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NATIONAL DAM SAFETY PROGRAM. THOMAS HILL RESERVOIR DAM (MO 1013--ETC(U)

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1 of 3

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LEVEL II

GRAND-CHARITON BASIN

THOMAS HILL RESERVOIR DAM

RANDOLPH COUNTY, MISSOURI

MO 10134

PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

United States Army
Corps of Engineers
...Serving the Army
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St. Louis District

PREPARED BY: U.S. ARMY ENGINEER DISTRICT, ST. LOUIS

FOR: STATE OF MISSOURI

MAY, 1980

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This report was prepared under the National Program of Inspection of Non-Federal Dams. This report assesses the general condition of the dam with respect to safety, based on available data and on visual inspection, to determine if the dam poses hazards to human life or property.

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THOMAS HILL RESERVOIR DAM
RANDOLPH COUNTY, MISSOURI
MISSOURI INVENTORY NO. MO 10134

PHASE I INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM

PREPARED BY
HOSKINS-WESTERN-SONDEREGGER, INC.
CONSULTING ENGINEERS
LINCOLN, NEBRASKA

UNDER DIRECTION OF

ST. LOUIS DISTRICT, CORPS OF ENGINEERS

FOR

GOVERNOR OF MISSOURI

MAY, 1980

DEPARTMENT OF THE ARMY
ST. LOUIS DISTRICT, CORPS OF ENGINEERS
210 TUCKER BOULEVARD, NORTH
ST. LOUIS, MISSOURI 63101

REPLY TO
ATTENTION OF

SUBJECT: THOMAS HILL RESERVOIR DAM - MO 10134

This report presents the results of field inspection and evaluation of the Thomas Hill Reservoir Dam. It was prepared under the National Program of Inspection of Non-Federal Dams.

SUBMITTED BY: SIGNED 17 SEP 1980
Chief, Engineering Division Date

APPROVED BY: SIGNED 19 SEP 1980
Colonel, CE, District Engineer Date

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

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PHASE I REPORT
NATIONAL DAM SAFETY PROGRAM
ASSESSMENT SUMMARY

Name of Dam	Thomas Hill Reservoir Dam
State Located	Missouri
County Located	Randolph County
Stream	Middle Fork of Chariton River
Date of Inspection	May 7, 1980

Thomas Hill Reservoir Dam was inspected by an interdisciplinary team of engineers. ~~from Hoskins-Western-Sonderegger, Inc.~~ The purpose of the inspection was to make an assessment of the general conditions of the dam with respect to safety, based upon available data and visual inspection, in order to determine if the dam poses hazards to human life or property.

The guidelines used in the assessment were furnished by the Department of the Army, Office of the Chief of Engineers and developed with the help of several Federal and State agencies, professional engineering organizations, and private engineers.

Thomas Hill Reservoir Dam has a height of seventy-two (72) feet and a storage capacity at the minimum top elevation of the dam of two hundred sixty thousand four hundred and fifty-eight (260,458) acre-feet. In accordance with the guidelines, a large size dam has a height greater than or equal to one hundred (100) feet and a storage capacity greater than or equal to fifty thousand (50,000) acre-feet. The size classification is determined by either the storage capacity or the height whichever gives the larger size category. Thomas Hill Reservoir Dam is classified as a large size dam.

In accordance with the guidelines and based on visual observation, the dam is classified as having a significant potential for damage and loss of life. Failure would threaten life and property. The estimated damage zone extends approximately sixteen (16) miles downstream from the dam. Within the damage zone are two power transmission lines and a strip mine area, in the first three miles, a State Highway 3 crossing at 3 miles, a crossing of U.S. Highway 24 at 12 miles and several dwellings with outbuildings between 12 and 16 miles downstream.

Our inspection and evaluation indicates that the spillways meet the criteria set forth in the recommended guidelines for a large dam having a significant hazard potential. The Probable Maximum Flood is the appropriate spillway design flood. The spillways will pass the one percent probability flood (flood having a one percent chance of being exceeded in any year) and also the Probable Maximum Flood without overtopping the dam. The Probable Maximum Flood (PMF) is defined as the flood that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region.

The construction plans and a Geotechnical Safety Evaluation report dated 1978 were available for this dam. Based on review of the plans, the report and on observations made during the field inspection, the following recommendations are made:

a. Measures should be taken to monitor the amount and clarity of seepage discharging from both abutment troughs. These discharge records should be included in the project files.

b. Piezometers should be read at least once a year. Data should become a part of the project files.

c. Additional seepage analyses should be performed by an engineer experienced in earth dam design using data collected from present and/or additional piezometers.

The following recommendations are made in regard to the maintenance of the dam:

a. Trees should be removed from the downstream section of the dam and from the emergency spillway exit channel. Tree removal should be done under the guidance of an engineer experienced in the design and construction of dams. Measures should be taken to prevent their recurrence.

b. Erosional gullies in the downstream section should be refilled, compacted and revegetated.

c. Periodic mowing of vegetation on the downstream slope would facilitate early detection and correction of erosional problems.

d. Installation of a stabilized gutter or drain with controlled and stable outlets along the downstream crest line of the dam would eliminate much of the present erosion on the downslope and minimize the maintenance needed to keep this problem under control.

e. Installation and maintenance of a good drain ditch along the toe of the downstream berm is suggested. Monitoring the discharge from this drain would assist in future evaluation studies concerning safety of this structure.

f. A program to provide for periodic inspection of the dam, similar to but not as detailed as the 1978 Geotechnical Safety Evaluation, should be initiated.

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Harold P. Hoskins, Chairman of the Board
Hoskins-Western-Sonderegger, Inc.
E-8696

PHOTO NO. 1 - OVERVIEW

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
THOMAS HILL RESERVOIR DAM - MO 10134
RANDOLPH COUNTY, MISSOURI

SECTION 1 - PROJECT INFORMATION

1.1 GENERAL

a. Authority. The National Dam Inspection Act, Public Law 92-367, authorized the Secretary of the Army through the Corps of Engineers, to initiate a program of safety inspection of dams throughout the United States. Pursuant to the above, the St. Louis District, Corps of Engineers, District Engineer directed that a safety inspection of Thomas Hill Reservoir Dam be made.

b. Purpose of Inspection. The purpose of the inspection was to make an assessment of the general condition of the dam with respect to safety, based upon available data and visual inspection, in order to determine if the dam poses hazards to human life or property.

c. Evaluation Criteria. Criteria used to evaluate the dam were furnished by the Department of the Army, Office of the Chief of Engineers, in "Recommended Guidelines for Safety Inspection of Dams, "Appendix D to "Report of the Chief of Engineers on the National Program of Inspection of Dams," dated May, 1975, and published by the Department of the Army, Office of the Chief of Engineers.

1.2 DESCRIPTION OF PROJECT

a. Description of Dam and Appurtenances.

(1) The dam is a moderately large earth fill located on the Middle Fork of the Chariton River in the northwestern section of Randolph County. The dam creates a large reservoir to serve the Associated Electric Cooperative generating plant located near the dam. The dam is about 2450 feet in length with maximum height of 72 feet above the old stream bed and 57 feet above the prepared base. The maximum water storage at the minimum top elevation of the dam is 260,458 acre-feet.

(2) The principal spillway is uncontrolled and consists of a 9' x 18' reinforced concrete drop inlet riser connected to a 9' diameter concrete lined tunnel. The tunnel is located in the left abutment and terminates at a hydraulic jump (St. Anthony Falls type) stilling basin. A 3' diameter drawdown port controlled with a rising stem valve is located in the riser approximately midway down from the crest of the riser. An 8-inch diameter cast iron pipe is also

located approximately midway down from the crest of the riser to maintain a minimum flow below the dam of 5 c.f.s.

(3) An uncontrolled emergency spillway is excavated through bedrock on the right abutment. The spillway has a bottom width of 50 feet. A reinforced concrete ogee weir control section is located on the centerline of the dam.

(4) Pertinent physical data are given in paragraph 1.3 below.

b. Location. The dam is located in the northwestern section of Randolph County, northwest of Moberly, Missouri. It is located in the SE¼ of Section 24, T25N, R16W.

c. Size Classification. Criteria for determining the size classification of dams and impoundments are presented in the guidelines referenced in paragraph 1.1c above. Thomas Hill Reservoir Dam has a height of 72 feet and a storage capacity at the minimum top elevation of the dam of 260,458 acre-feet. This dam is classified as a large size dam. A large size dam has a height greater than or equal to 100 feet and a storage capacity greater than or equal to 50,000 acre-feet. The size classification is determined by either the storage capacity or height, whichever gives the larger size category.

d. Hazard Classification. Guidelines for determining hazard classification are presented in the same guidelines as referenced in paragraph 1.1c above. Based on referenced guidelines, this dam is in the Significant Hazard Classification. The estimated damage zone extends approximately 16 miles downstream from the dam. Within the damage zone are two power transmission lines and a strip mine area, in the first three miles, a State Highway 3 crossing at 3 miles a crossing of U.S. Highway 24 at 12 miles and several dwellings with outbuildings between 12 and 16 miles downstream.

e. Ownership. The dam and reservoir is owned by the Associated Electric Cooperative, Inc., 2814 So. Golden Street, P.O. Box 754, Springfield, Missouri 65801.

f. Purpose of Dam. The dam impounds a 56000+ acre foot reservoir to supply cooling water for a coal fired power generating plant.

g. Design and Construction History. The dam was designed by Burns and McDonnell, Kansas City, Missouri and constructed in 1966 by Eby Construction Co., Omaha, Nebraska. Portions of the construction plans for the dam are included as Appendix C. A copy of the Geotechnical Safety Evaluation Study of the dam made in 1978 by Burns and McDonnell is included as Appendix E of this report.

h. Normal Operating Procedure. The reservoir level is dependent upon natural precipitation and the capacity of the uncontrolled spillways. The principal spillway is designed to accomodate removable stop logs above the weir crest to provide an operating reservoir elevation of 710.0. At the time of inspection the operating level was elevation 709.5 with about 0.5 foot of flow over the crest of the riser (apparently one stop log was removed).

1.3 PERTINENT DATA

a. Drainage Area. 94,080 acres (147 square miles).

b. Discharge at Damsite.

(1) All discharges at the damsite are through an uncontrolled reinforced concrete drop inlet (riser) with a reinforced concrete conduit through the dam and an uncontrolled chute type spillway cut through bedrock in the right abutment with a concrete ogee sill control section.

(2) Estimated maximum flood. The water level rose to approximately one foot below the emergency spillway crest from a storm which occurred in 1973. This information was reported by Mr. Paul Smith, plant superintendent.

(3) The principal spillway capacity varies from 8 c.f.s. at elevation 709.0 feet (weir crest) to 2,087 c.f.s. at elevation 717.0 feet (emergency spillway crest) to 2,528 c.f.s. at elevation 737.4 feet (minimum top of dam). An 8-inch cast iron pipe is located at elevation 688.0 feet in the spillway to maintain a minimum flow of 5 c.f.s. below the dam at all times.

(4) The emergency spillway capacity varies from 0 c.f.s. at its crest elevation 717.0 feet to 13,575 c.f.s. at elevation 737.4 (minimum top of dam).

(5) Total spillway capacity at the minimum top of dam is 16,103 c.f.s. ±.

c. Elevations. (Feet above M.S.L.)

(1) Top of dam - 737.0 (Plans); 737.4 (Minimum Measured by Inspection Team)

(2) Principal spillway crest and normal pool - 709.0 (Weir Crest)

(3) Emergency spillway crest - 717.0

(4) Streambed at centerline - 680±

(5) Observed Pool - 709.5

(6) Maximum Experienced Pool - 716± (April, 1973)

(7) Lowest Pool - 707 (1978)

(8) Maximum tailwater - Unknown

d. Reservoir.

(1) Length (feet) of pool at top of dam - 76,000±

(2) Length (feet) of pool at principal spillway crest - 45,800±

(3) Length (feet) of pool at emergency spillway crest - 54,600±

e. Storage (Acre-feet).

(1) Top of dam - 260,458

(2) Principal spillway crest and normal pool - 56,328

(3) Emergency spillway crest - 96,385

(4) Observed pool - 58,484

(5) Maximum experienced pool - 95,222

f. Reservoir Surface (Acres).

(1) Top of dam - 11,500±

(2) Principal spillway crest and normal pool - 4,214

(3) Emergency spillway crest - 5,793

(4) Observed pool - 4,310

(5) Maximum experienced pool - 5,750

g. Dam.

(1) Type - Earth fill

(2) Length - 2450 feet ±

(3) Height - 57 feet above prepared base (measured)

(4) Top width - 26 feet (roadway and riprap) measured

(5) Side slopes.

(a) Downstream - Plans = 1V/2.5/4/12H; Measured 1V/2.7/4.2/11.3H

(b) Upstream - Plans = 1V/2.5/4/13.5H; Measured 1V/2/2.9H

(6) Zoning - Plans show impervious fill center section with berm (random) fill upstream and downstream.

(7) Impervious core - Center section

(8) Cutoff - Exploration trench 5 to 10 feet in depth.

(9) Grout curtain - Both abutments; Left = Station 15+50 to 25+50±; Right = Station 32+00 to 37+25±

(10) Wave protection - Durable rock riprap.

(11) Drain blanket under downstream section

(12) Three relief wells at downstream toe between Stations 26+50 to 30+50.

h. Diversion Channel and Regulating Tunnel. Uncontrolled principal spillway tunnelled through left abutment.

i. Spillway.

(1) Principal

(a) Type - uncontrolled reinforced concrete drop inlet with removable stop logs on crest and 9 foot diameter concrete lined outlet tunnel through left abutment.

(b) Crest (invert) elevation - concrete weir = 709; Stop logs at 710.0

Outlet - Tunnel invert 667.9; stilling basin = 661

(c) Length - Tunnel = 165 feet.

(2) Emergency

(a) Type - Excavated cut in limestone and shale through right abutment, 50 foot bottom width and 1V on 1H side slopes.

(b) Control Section - Reinforced concrete sill with ogee weir.

(c) Crest elevation - 717 feet

(d) Upstream Channel - excavated, 50 foot bottom, near level at elevation 715± for 300 feet ±.

(e) Downstream Channel - excavated 400 feet± long; slope = less than 1%.

j. Regulating Outlets. Drawdown facility, 36-inch diameter into riser with rising stem valve.

SECTION 2 - ENGINEERING DATA

2.1 DESIGN

Design data and plans for the structure were made available from Burns and McDonnell, Consulting Engineers, Kansas City, Missouri. This information is shown in Appendix C. Several attempts were made to secure the Geotechnical data and report for design of the dam without success. Some of the Geotechnical data are reported in the report on Geotechnical Safety Evaluation of the dam by Burns and McDonnell, 1978 which is included in this report as Appendix E.

The design includes a prepared (compacted impervious fill) base for the embankment across the valley bottom up to elevation 680. A 3-foot thick sand blanket, placed on the prepared base, extends from the downstream toe upstream for a distance of 0.8B where B is the base width of the downstream section (℄ to toe). The blanket drain extends from Station 24+00 to 35+00±. Between Stations 25+00 and 32+00±, the sand blanket outlets into the riprapped toe of the downstream berm at elevation 680. Included in the design are 5 piezometers and 3 settlement plates located upstream, downstream and on the crest line. Three relief wells are located along the toe of the dam.

2.2 CONSTRUCTION

The dam was constructed in 1965-66 by Eby Construction Co., Omaha, Nebraska. Measurements indicate that the dam was constructed essentially according to the plans. Settlement plate readings made during and after construction indicate that anticipated foundation settlement occurred during the construction period. The Geotechnical Safety Evaluation Report of 1978 states that construction control records were reviewed and that construction conformed with specifications.

2.3 OPERATION

No data were available on spillway operation. It was reported by Paul Smith, Associated Electric Cooperative Power Plant Superintendent, that the emergency spillway has never operated. The highest reservoir level was about elevation 716 in 1973. The lowest reservoir level was about elevation 707 in 1978.

2.4 EVALUATION

a. Availability. Plans and other data included with this report were made available by Burns and McDonnell through Associated Electric Cooperative Inc., Springfield, Missouri. Geologic and Soil Mechanics data and Soil Engineering analyses were not available despite several requests.

b. Adequacy. The available data, field surveys, and visual observation presented herein are considered adequate to support the conclusions of this report. Seepage and stability analyses were not available. They were referenced in the 1978 Geotechnical Safety Evaluation Report by Burns and McDonnell which is considered adequate.

c. Validity. The data and analyses are considered valid and adequate.

SECTION 3 - VISUAL INSPECTION

3.1 FINDINGS

a. General. A visual inspection of the Thomas Hill Reservoir Dam was made on May 7, 1980. Engineers from Hoskins-Western-Sonderegger, Inc., Lincoln, Nebraska making the inspection were: R.S. Decker, Geotechnical; Garold Ulmer and Gordon Jamison, Hydrology. Messrs. Jerry Phelan and Fred Bader, St. Louis District Corps of Engineers, spent some time on site with the inspection team. Paul Smith, Plant Superintendent, was very cooperative in discussing the dam and in providing access to his files.

b. Dam.

(1) Geology and Soils (Abutment and embankment). The dam is located in the dissected till plains overlying Pennsylvanian limestone and shale. The abutments consist of 5 to 10 feet of clay till overlying silty/clayey shales and clayey sandstones. Photos 6 and 21 show the shale outcrops in the abutments. The valley section consists of alluvial clays, silts and sand-gravel deposits up to 40 feet in depth. Materials in the embankment consist of CL-CH soils borrowed from the reservoir area and the upstream right abutment.

(2) Upstream Slope. The upstream slope is well covered with good durable riprap consisting of limestone and quartzitic sandstone. Nominal size of the riprap was estimated at 24 to 30 inches. A few of the larger rocks (less than 5% of the total) showed signs of cracking and deterioration, but the riprap generally looked good. Measurements of the slope do not exactly conform with the plans; however, the measured overall slope is essentially equal to the planned compound slope. No obvious deformations were observed on the slope. Photos 3, 23, 30 and 31 show the upstream slope.

(3) Crest. The crest is constructed in two levels with a well gravelled roadway 24-feet wide running along the upstream side at elevation 737+ and a well vegetated, berm-like, lower level crest 27 feet wide adjacent to the roadway on the downstream side at about elevation 734.5. No obvious deformations or cracks were observed on the crest. Measurements along the crest show a maximum variation of about 1 foot in elevation with all measurements above the design elevation of 737. Plate C-21 shows the measured profile of the crest. Photo No. 2 shows the crest.

(4) Downstream Slope. The downstream slope is well vegetated with adapted grasses. A few small trees are growing on the slope and berm. No cracks, deformations or rodent activity were observed on the slope or berm. The toe slope of the berm is well covered with riprap. The downstream slope is shown in Photos 5, 19 and 37.

Several erosion gullies, up to 2 to 3 feet deep and 3 to 4 feet wide, were observed on the slope and the berm. Photos 15, 16 and 28 show the gullies on the slope. Seepage outcrops in the left abutment trough at about elevation 697 (downstream from about Station 24+50). Seepage effluent from the left abutment was estimated at less than 5 gpm. Seepage also outcrops in the right abutment trough at about the same elevation (697) as the right abutment seep. Flow from this seep was estimated at less than 0.5 gpm. All seepage was clear. These seeps in the abutment have existed since the reservoir filled, as shown by the following quotes from records of settlement plate and piezometer readings made in 1966 and supplied by the owner. "9-19-66-The east abutment is saturated to elevation 696.58 A flow approximately 3 gpm is measurable 80 feet south of Station 24+60. Another seep, at the same elevation, is evident on the west abutment near the head of the original ditch located 250 feet south of Station 35+50. The rate of flow is too low to be computable at this point." According to the plans, the areas upstream to the sides and below the elevations of the seeps are included in the grout curtain area.

It is assumed that the seeps are flowing through bedrock or near the till-bedrock contacts in the abutments, and that the grout curtain is not positive. A review of the original geologic investigation data might throw some light on the cause and source of these abutment seeps.

The entire area downstream from the berm is wet and boggy. This area apparently covers much of the old channel and was filled and graded as part of the designed base preparation. Part of this boggy condition results from the discharge of the relief wells. The blanket drain also discharges into this area. It was not possible to observe the blanket drain discharge. According to the Geotechnical Safety Evaluation Report of 1978, (Appendix E) this area was even wetter than at present prior to October 1977, when the area was cleared, "demucked" and partially drained.

All three relief wells were flowing at an estimated rate of 1-2 gpm, each,

Photos 7 and 8 show seep in the left abutment. Photos 17, 18, and 20 show seep in right abutment trough. Photos 11, 12, 13 show relief wells and discharges. Photos 9 and 10 show water standing along toe of the berm and total discharge from the left end of the toe of the berm.

c. Appurtenant Structures.

(1) The principal spillway consists of a drop inlet (riser) connected to a 9 foot diameter concrete lined tunnel bored through the left abutment. The outlet tunnel exits into a S.A.F. like stilling basin. The drop inlet structure is located in the lake, and it was not possible to inspect it. Photo No. 4 shows the inlet structure. Measurements indicate that the reservoir level was about 0.5 feet above the crest of the riser at the time of inspection. The outlet and energy dissipator appear to be in good condition. Photos 34, 35 and 36 show the outlet of the principal spillway. Measurements indicate that the principal spillway was constructed according to the plans.

(2) The emergency spillway consists of a 50 feet ± wide channel excavated through bedrock (limestone and shale) in the right abutment. The control section consists of a reinforced concrete sill and ogee weir located across the spillway bottom on the centerline of the dam. The ogee weir control section was constructed in 1978 in accordance with plans shown on Plate C-20. The spillway has never operated. The concrete control section appeared to be excellent condition. Photos 24, 25, 26 and 27 show the spillway approach section, control weir and portions of the outlet channel. The outlet channel has a few trees growing along both sides as shown in Photos 26 and 27. The exit channel, some 400 feet downstream from the control section, has a number of trees (up to 6-inch diameter) growing in the bottom of the channel as shown in Photos 28 and 29.

(3) Drawdown facilities consist of a 36-inch port on the upstream side of the riser which is controlled by a rising stem valve. Mr. Smith reported that the drawdown facility is operable but has not been opened for several years.

d. Reservoir Area. No significant erosion was noted around the waterline of the reservoir.

e. Downstream Channel. The channel downstream from the principal spillway is an excavated channel. It is open and clear as shown in Photo 36.

3.2 EVALUATION

This structure appears to have been designed and constructed in accordance with present day criteria for seepage control, slope stability, wave protection and overall safety. It appears to be in excellent condition, except for the few deficiencies in maintenance noted above.

Seepage through the abutments has occurred at about the same rate, from the first filling of the reservoir and does not appear to be detrimental to the stability of the structure.

The effects of seepage along the toe of the dam on stability of the structure are not known. The relief wells are operating and apparently dissipating any excess uplift pressures under the toe. However, it is felt that additional seepage and uplife analyses should be made based upon data collected from the new piezometers installed during the Burns and McDonnell Geotechnical Safety Evaluation Study in 1978.

Settlement plate records show no significant change since the end of construction.

SECTION 4 - OPERATIONAL PROCEDURES

4.1 PROCEDURES

There are no controlled outlet works for this dam. The pool level is controlled by rainfall, infiltration, evaporation, and the capacity of the uncontrolled spillways. There is a 36-inch diameter drawdown facility controlled with a rising stem valve that is operable, but it has not been opened for several years.

4.2 MAINTENANCE OF DAM

Maintenance of the structure is generally good. A few trees on the downstream slope and in the emergency spillway exit channel should be removed, and the erosional gullies on the downstream slope should be repaired.

4.3 MAINTENANCE OF OPERATING FACILITIES

No operating facilities, except the drawdown facility, exist at this dam.

4.4 DESCRIPTION OF ANY WARNING SYSTEM IN EFFECT

The plant superintendent was not aware of a warning system in effect for this dam.

4.5 EVALUATION

The deficiencies observed during the inspection can be corrected with an improvement in the maintenance program.

SECTION 5 - HYDRAULIC/HYDROLOGIC

5.1 EVALUATION OF FEATURES

a. Design Data. Plans for the dam and a "Hydrology Report", as prepared by Burns and McDonnell, Kansas City, Missouri, were obtained from the Associated Electric Cooperative. The plans for the dam are shown in Appendix C. The "Hydrology Report" is shown in Appendix D.

b. Experience Data. The drainage area, reservoir surface area, and elevation-storage data were developed from the data prepared by Burns and McDonnell and presented in the plans and "Hydrology Report" and were verified using the following USGS 7.5 minute quadrangle maps: Elmer, Barnesville, New Cambria East, Bevier North, Lagonda, Bevier South, Prairie Hill and College Mound (See Plate A-3). The hydraulic computations for the spillways and dam overtopping discharge ratings were based on the plans and data collected in the field at the time of the field inspection. A discussion of the hydraulic computations is included in Appendix D.

c. Visual Observations.

(1) The principal or service spillway appeared to be in good condition. The reservoir was discharging at approximately 0.5 feet over the weir crest at the time of inspection. One stop log had apparently been removed from the weir crest at the time of inspection.

(2) The stilling basin and exit channel appeared to be in good condition. The exit channel was straight and uniform and was clear of debris and weeds. (See Photos 34, 35 and 36)

(3) The emergency spillway is located in the right abutment and is cut into bedrock. It appeared to be in good condition with the side slopes being riprapped above the limestone outcroppings. There were, however, a few trees located in the exit channel. Spillway releases will not endanger the integrity of the dam. (See Photos 28 and 29).

(4) The spillway control section (ogee crest) appeared to be in excellent condition. (See Photos 25 and 26.)

d. Overtopping Potential. The spillways will pass the probable maximum flood without overtopping the dam. The results of the routings through the dam are tabulated in regards to the following conditions:

Frequency	Inflow Discharge c.f.s.	Outflow Discharge c.f.s.	Maximum Pool Elevation	*Maximum Depth Over Dam	Duration Overtop Hr.
1/2 PMF	40,400	4,700	724.2	0	0
PMF	80,800	12,200	733.8	0	0

*Minimum Top of Dam Elevation = 737.4

According to the recommended guidelines from the Department of the Army, Office of the Chief of Engineers, this dam is classified as having a significant hazard rating and a large size. Therefore, the PMF is the test for the adequancy of the dam and its spillway.

The estimated damage zone is described in Paragraph 1.2d in this report.

SECTION 6 - STRUCTURAL STABILTY

6.1 EVALUATION OF STRUCTURAL STABILITY

a. Visual Observation. This dam appears to be structurally stable. Testing and analyses presented in the Geotechnical Safety Evaluation Report (Appendix E) indicate that it is stable against shear failures. The effects of seepage along the toe of the dam on structural stability are not known. Seepage through the abutments does not appear to be detrimental to the structural stability.

b. Design and Construction Data. Hydrologic design data were available. No other design or construction data were available, except for the construction plans and the Geotechnical Safety Evaluation Report made by Burns and McDonnell in 1978. According to the Geotechnical Safety Evaluation Report, the present dam fulfills the criteria used for design, and the construction records that were reviewed indicated that construction specifications were fulfilled.

c. Operating Records. There are no controlled operating facilities for this dam except for the drawdown facility which has not been operated for several years.

d. Post Construction Changes. Original plans show a concrete sill control section at elevation 715 in the emergency spillway. The present ogee weir section, with crest at elevation 717, was constructed in 1978. Plans for this modification are shown on Plate C-20.

e. Seismic Stability. This dam is located in Seismic Zone I. An earthquake of the magnitude predicted in this area is not expected to cause structural failure of this dam.

SECTION 7 - ASSESSMENT/REMEDIAL MEASURES

7.1 DAM ASSESSMENT

a. Safety. This dam appears to be in excellent condition and does not appear to have any serious potential of failure. Analyses presented in Section 5, indicate that the spillways will pass the PMF without overtopping the dam. Seepage through the abutments is apparently about the same as when the dam was first constructed. Additional studies should be made to determine the effects of seepage along the downstream toe. A few deficiencies in maintenance; (gullies on downstream slope and berm, tree growth on the downstream slope and in the emergency spillway exit, ponded water and poor drainage along the downstream toe) should be corrected.

b. Adequacy of Information. Information available on design and construction and data collected during the inspection are considered adequate to justify the conclusions presented in this report. Seepage and stability analyses referenced in the Geotechnical Safety Evaluation Report (Appendix E) are considered adequate.

c. Urgency. There does not appear to be an immediate urgency to accomplish the remedial measures recommended in paragraph 7.2.

d. Necessity for Further Studies. Further studies as stated in paragraph 7.2b related to monitoring seepage are recommended.

e. Seismic Stability. This dam is located in Seismic Zone 1. An earthquake of this magnitude is not expected to be hazardous to this dam.

7.2 REMEDIAL MEASURES

a. Alternatives.

(1) Since the project accommodates the Probable Maximum Flood no alternatives are required.

b. Operation and Maintenance Procedures.

(1) It is recommended that measures be taken to monitor the amount and clarity of seepage discharging from both abutment troughs and that these discharge records be included in the project files.

(2) It is also recommended that the piezometers be read at least once a year and that these data become a part of the project files.

(3) Additional seepage analyses should be performed, by an engineer experienced in earth dam design, using data collected from present and/or additional piezometers.

(4) Trees should be removed from the downstream section of the dam and from the emergency spillway exit channel. Tree removal should be done under the guidance of an engineer experienced in the design and construction of dams. Measures should be taken to prevent their recurrence.

(5) Erosional gullies in the downstream section should be refilled, compacted and revegetated.

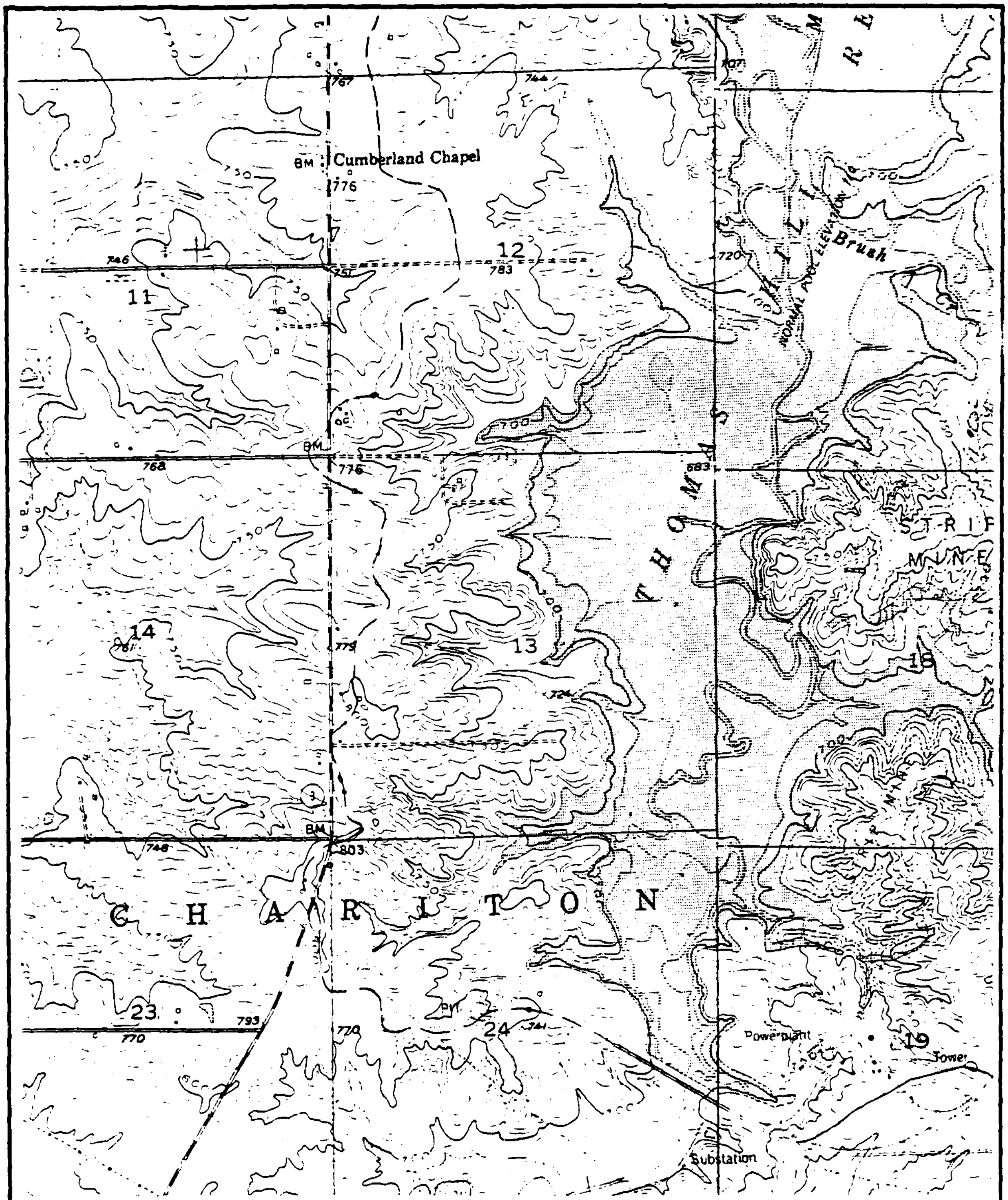
(6) Periodic mowing of vegetation on the downstream slope would facilitate early detection and correction of erosional problems.

(7) Installation of a stabilized gutter or drain with controlled and stable outlets along the downstream crest line of the dam would eliminate much of the present erosion on the downslope and minimize the maintenance needed to keep this problem under control.

(8) Installation and maintenance of a good drain ditch along the toe of the downstream berm is suggested. Monitoring the discharge from this drain would assist in future evaluation studies concerning safety of this structure.

(9) A program to provide for periodic inspection of the dam, similar to but not as detailed as the 1978 Geotechnical Safety Evaluation, should be initiated.

APPENDIX A
MAPS



Scale in feet

2000 1000 0 2000 4000

Contour Interval - 10'

N

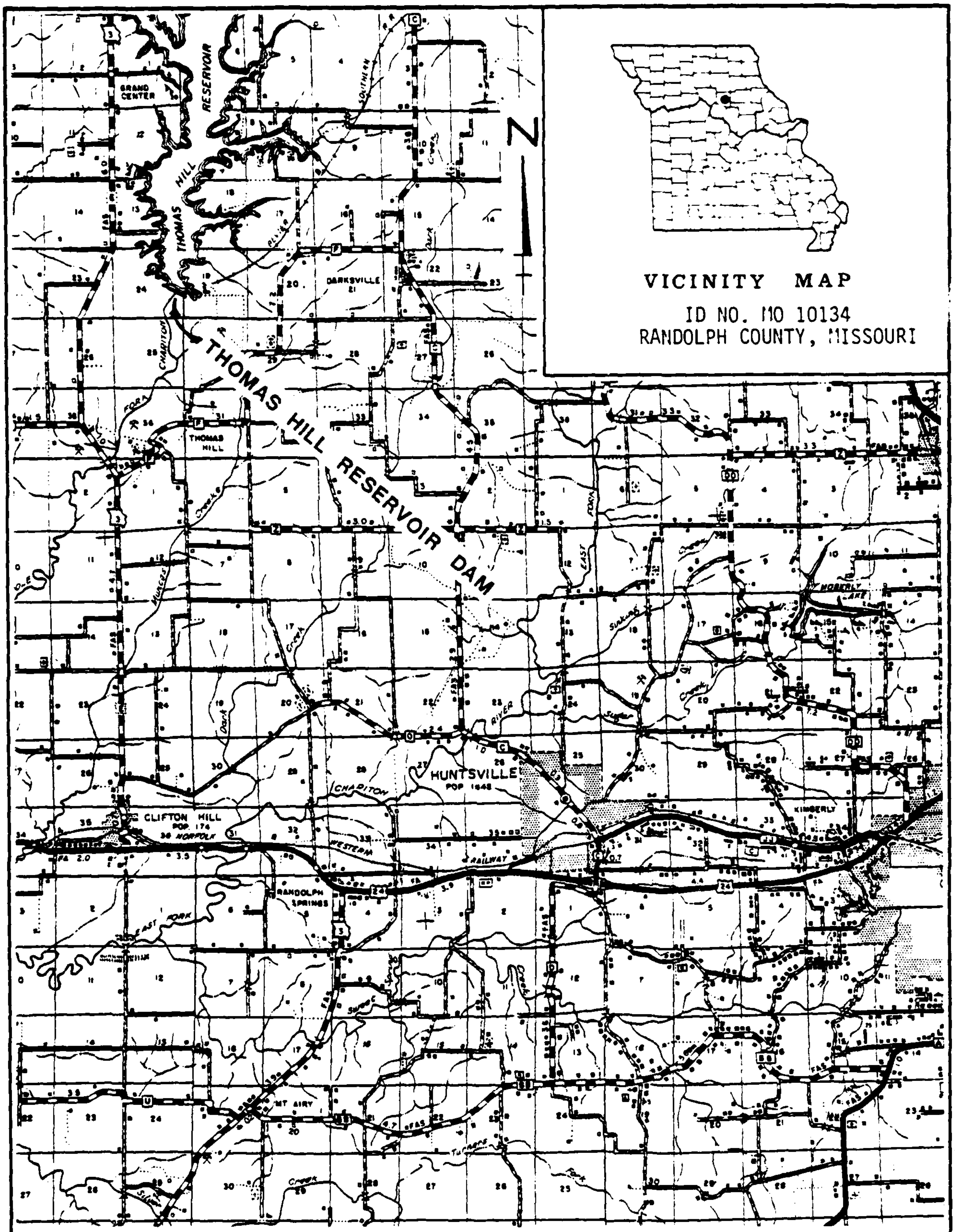
VICINITY TOPOGRAPHY

THOMAS HILL RESERVOIR DAM

RANDOLPH COUNTY, MISSOURI

MO 10134

PLATE A-1

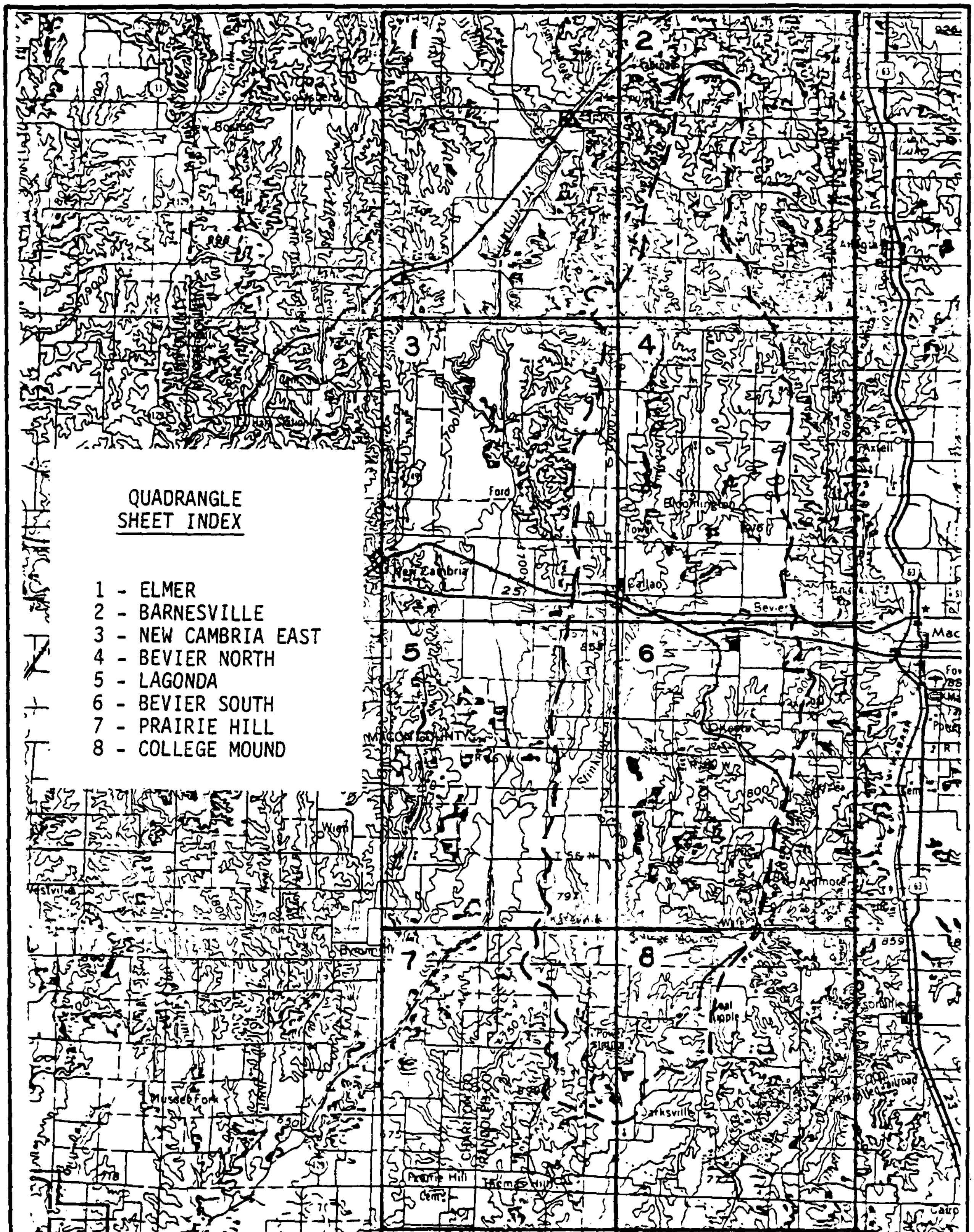


Scale in miles

0 1 2 3 4 5

LOCATION MAP

PLATE A-2



THOMAS HILL RESERVOIR DAM

RANDOLPH COUNTY, MISSOURI

MO 10134

DRAINAGE AREA MAP

PLATE A-3

APPENDIX B
PHOTOGRAPHS

THOMAS HILL RESERVOIR DAM RANDOLPH COUNTY, MISSOURI MO 10134	**PHOTO INDEX** PLATE B-1

PHOTO NO. 2 - CREST FROM LEFT END

PHOTO NO. 3 - UPSTREAM SLOPE FROM LEFT SIDE

PHOTO NO. 4 - PRINCIPAL SPILLWAY INLET

PHOTO NO. 5 - DOWNSTREAM SLOPE FROM LEFT END

PHOTO NO. 6 - SHALY OUTCROPS IN LEFT ABUTMENT

PHOTO NO. 7 - LARGE SEEPAGE AREA IN LEFT ABUTMENT TROUGH

PHOTO NO. 8 - SEEPAGE DISCHARGE AT OUTLET END OF LEFT ABUTMENT

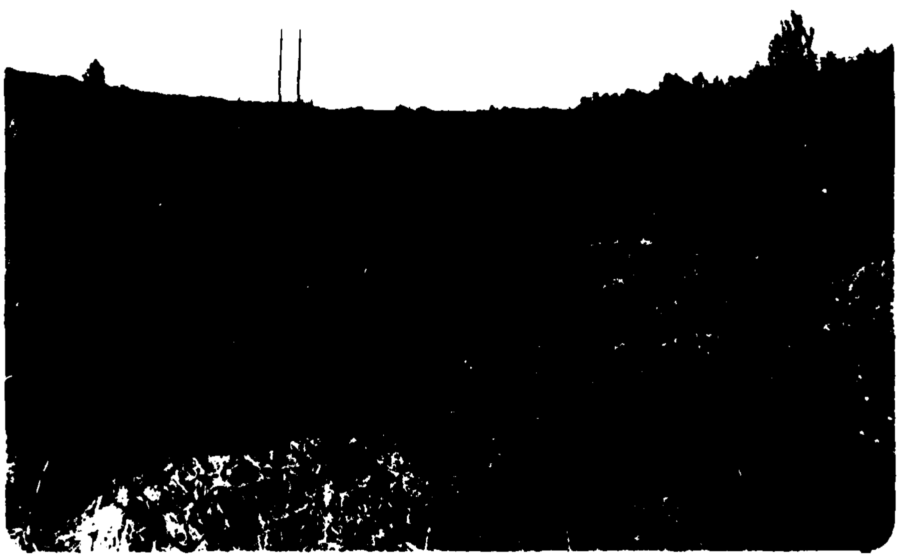


PHOTO NO. 9 - WATER STANDING ALONG THE TOE OF DAM

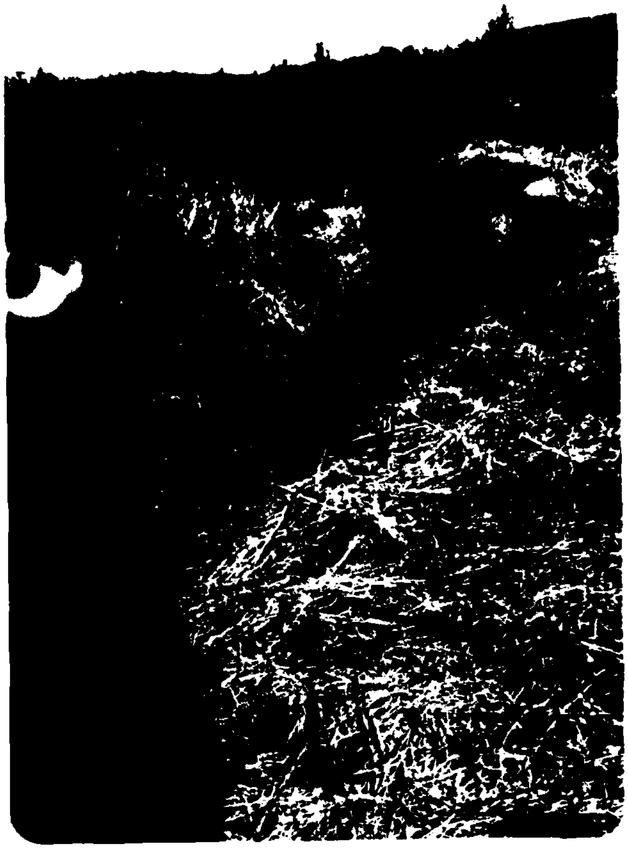


PHOTO NO. 10 - DITCH DRAIN-
ING SEEPAGE AWAY FROM TOE

PHOTO NO. 11 - DISCHARGE
FROM LEFT RELIEF WELL

PHOTO NO. 12 - LEFT RELIEF WELL IN FOREGROUND

PHOTO NO. 13 - DISCHARGE FROM MIDDLE RELIEF WELL

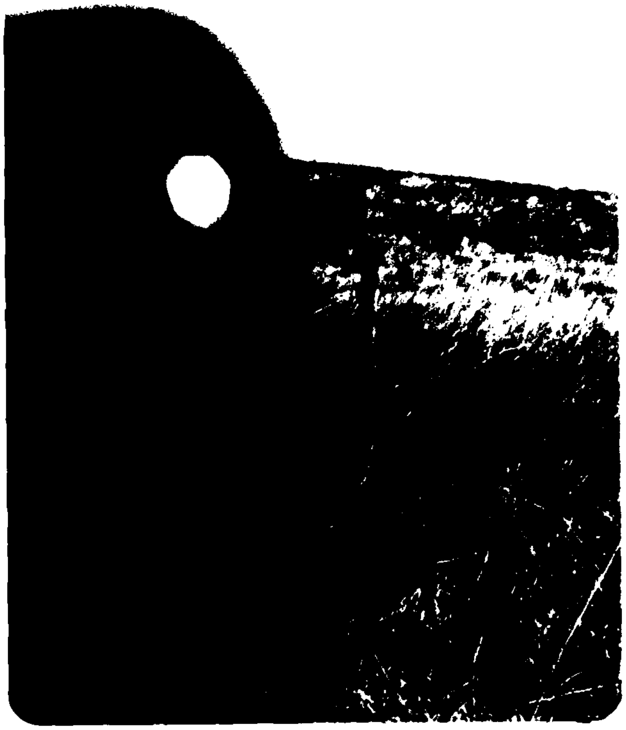


PHOTO NO. 14 - ALIGNMENT OF THREE PIEZOMETERS LOOKING UPSTREAM FROM RIGHT RELIEF WELL

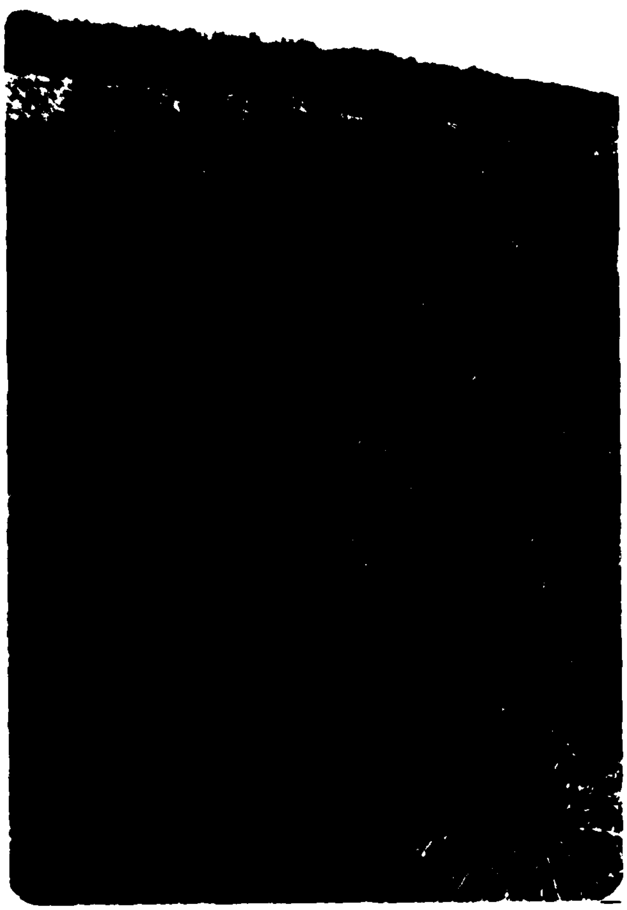


PHOTO NO. 15 - GULLY IN DOWNSTREAM SLOPE AND BERM

PHOTO NO. 16 - GULLY DOWN DOWNSTREAM SLOPE AT STA. 31+00$\pm$

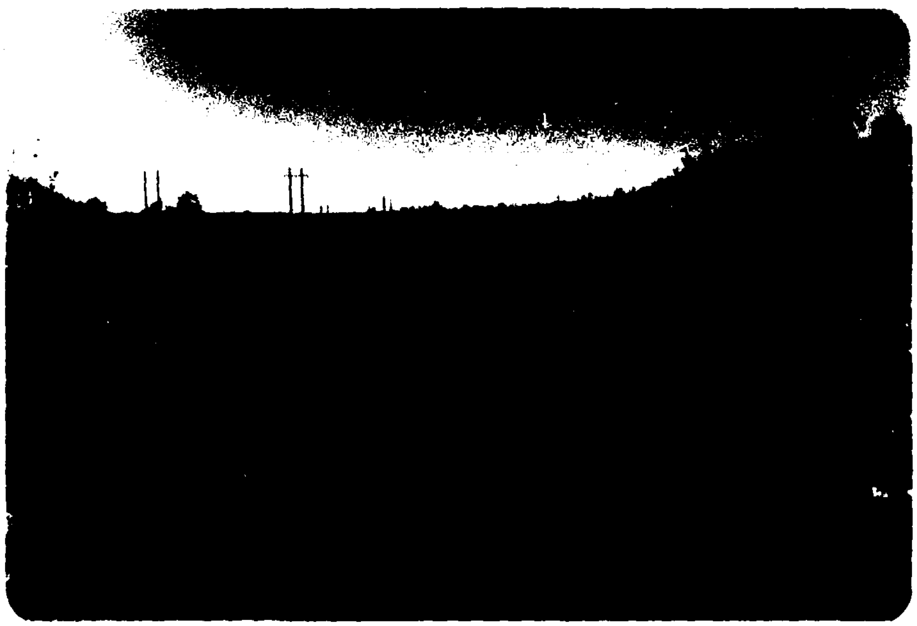


PHOTO NO. 17 - SEEP IN RIGHT ABUTMENT TROUGH

PHOTO NO. 18 - DISCHARGE FROM SEEP AREA TO RIGHT OF RIGHT ABUTMENT TROUGH

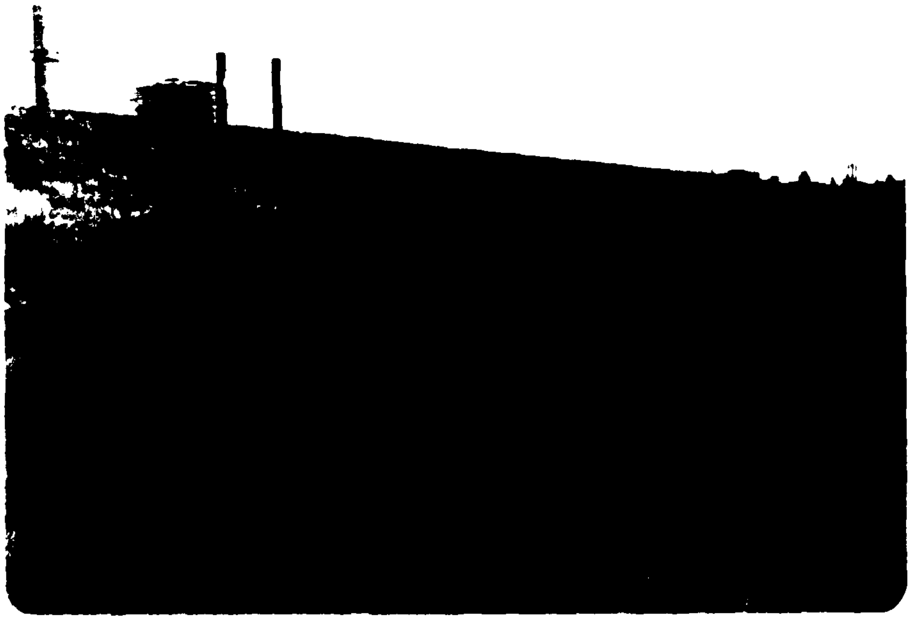


PHOTO NO. 19 - DOWNSTREAM SLOPE FROM RIGHT SHOWING ROCK COVERING TOE OF BERM

PHOTO NO. 20 - SEEPAGE DOWSNTREAM FROM RIGHT ABUTMENT TROUGH

PHOTO NO. 21 - WEATHERED SILTY SHALE IN RIGHT ABUTMENT

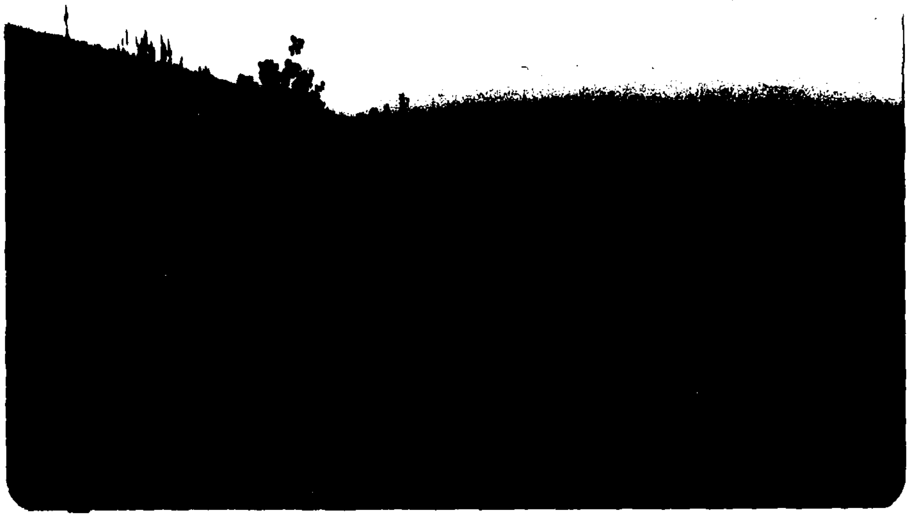


PHOTO NO. 22 - DOWNSTREAM SLOPE FROM RIGHT END

PHOTO NO. 23 - UPSTREAM SLOPE FROM RIGHT END

PHOTO NO. 24 - VIEW UPSTREAM SHOWING EMERGENCY SPILLWAY ENTRANCE

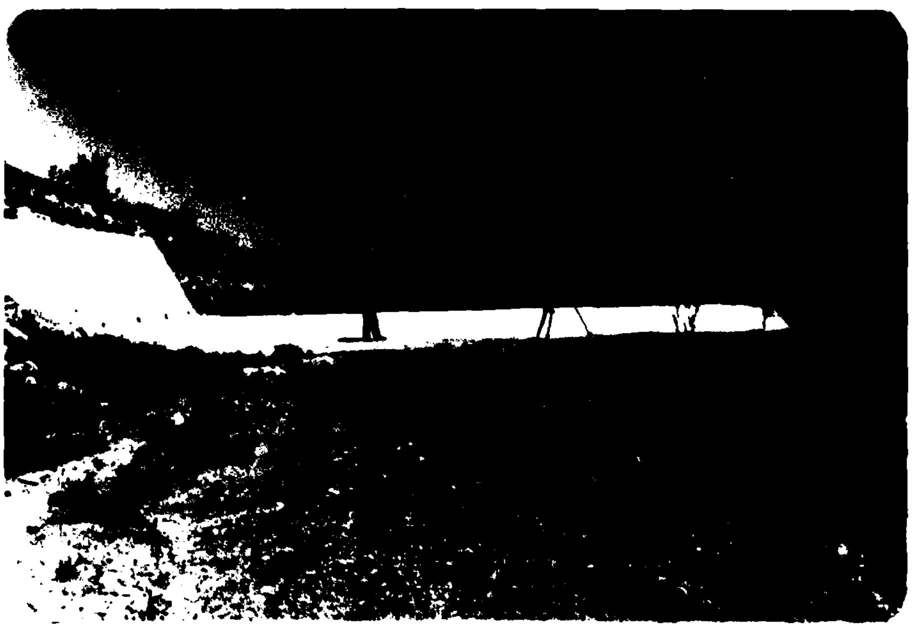


PHOTO NO. 25 - VIEW UPSTREAM IN EMERGENCY SPILLWAY SHOWING CONTROL WEIR

PHOTO NO. 26 - VIEW DOWNSTREAM IN EMERGENCY SPILLWAY

PHOTO NO. 27 - GREY AND TAN SILTY SILTSTONE AND LIMESTONE EXPOSED
IN RIGHT SIDE OF SPILLWAY EXIT CHANNEL

PHOTO NO. 28 - EXIT CHANNEL FROM SPILLWAY

PHOTO NO. 29 - VIEW UPSTREAM INTO SPILLWAY. PHOTO TAKEN APPROX. 50 FEET FROM EXIT CHANNEL

PHOTO NO. 30 - UPSTREAM FACE TAKEN ABOUT CENTERLINE LOOKING TO RIGHT

PHOTO NO. 31 - SETTLEMENT GAUGE NO. 1 AT STATION 27+50±

PHOTO NO. 32 - VIEW OF RESERVOIR FROM STATION 25+50±

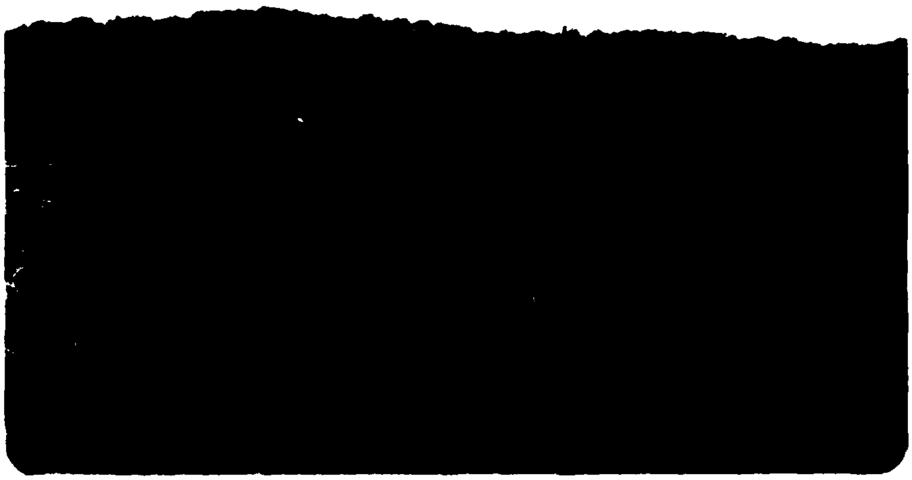


PHOTO NO. 33 - VIEW DOWNSTREAM FROM STATION 25+50±

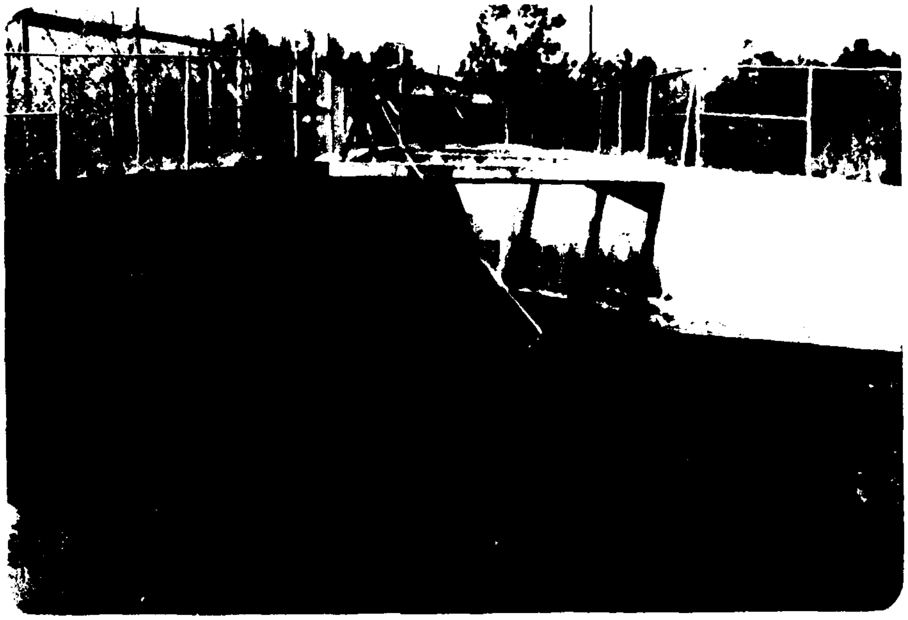


PHOTO NO. 34 - VIEW OF PRINCIPAL SPILLWAY OUTLET

PHOTO NO. 35 - OUTLET OF PRINCIPAL SPILLWAY FROM DOWNSTREAM

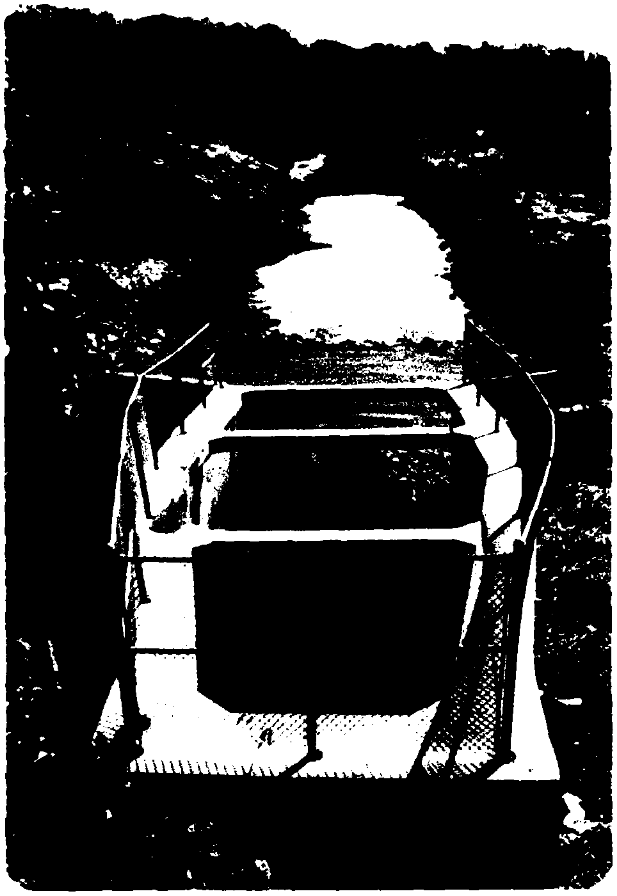


PHOTO NO. 36 - VIEW DOWNSTREAM SHOWING OUTLET CHANNEL OF PRINCIPAL SPILLWAY

PHOTO NO. 37 - DOWNSTREAM SLOPE FROM LEFT SHOWING SEEP AREA IN LEFT ABUTMENT TROUGH

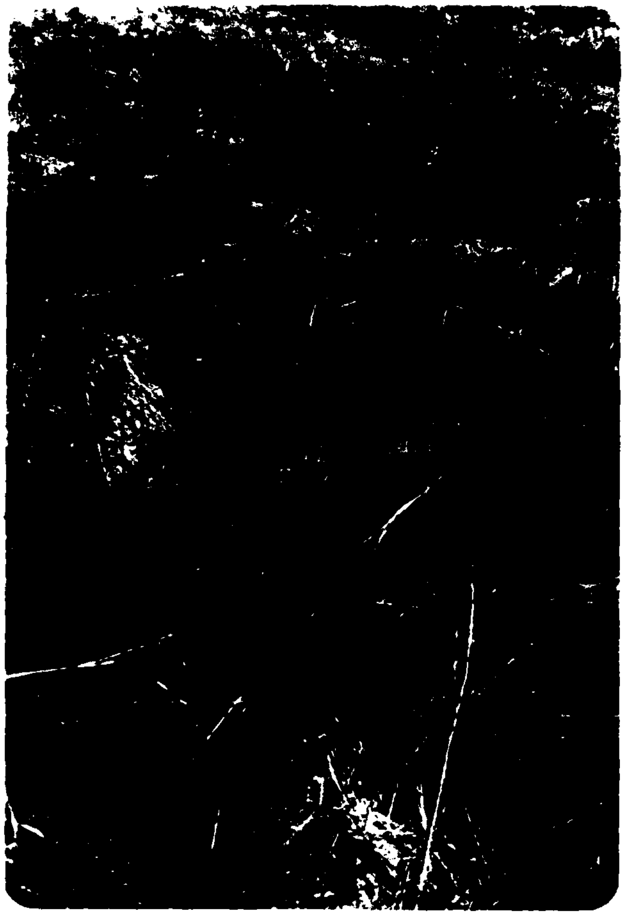


PHOTO NO. 38 - LOOKING DOWNSTREAM AT GULLY IN DOWNSTREAM FACE AT STATION 27+70±

PHOTO NO. 39 - SEEP AREAS IN RIGHT ABUTMENT TROUGH. PHOTO TAKEN FROM STATION 37+50

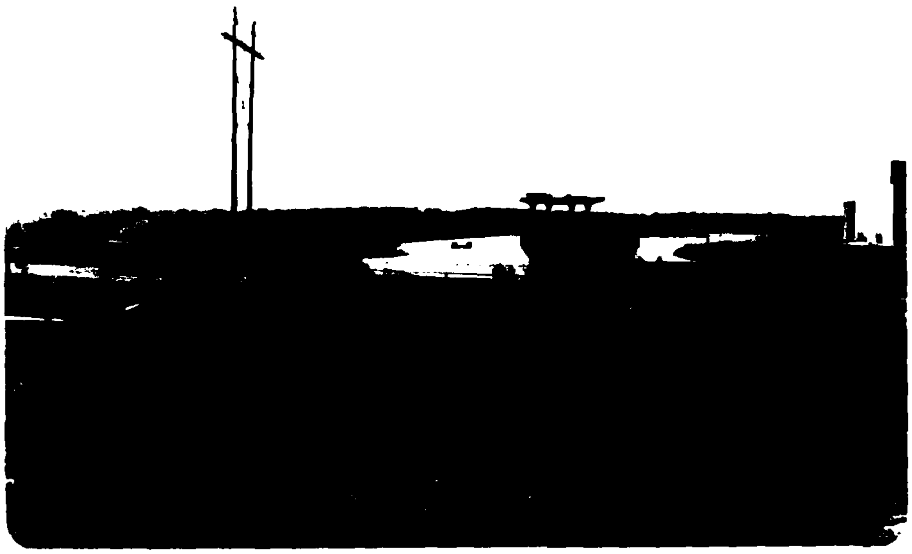
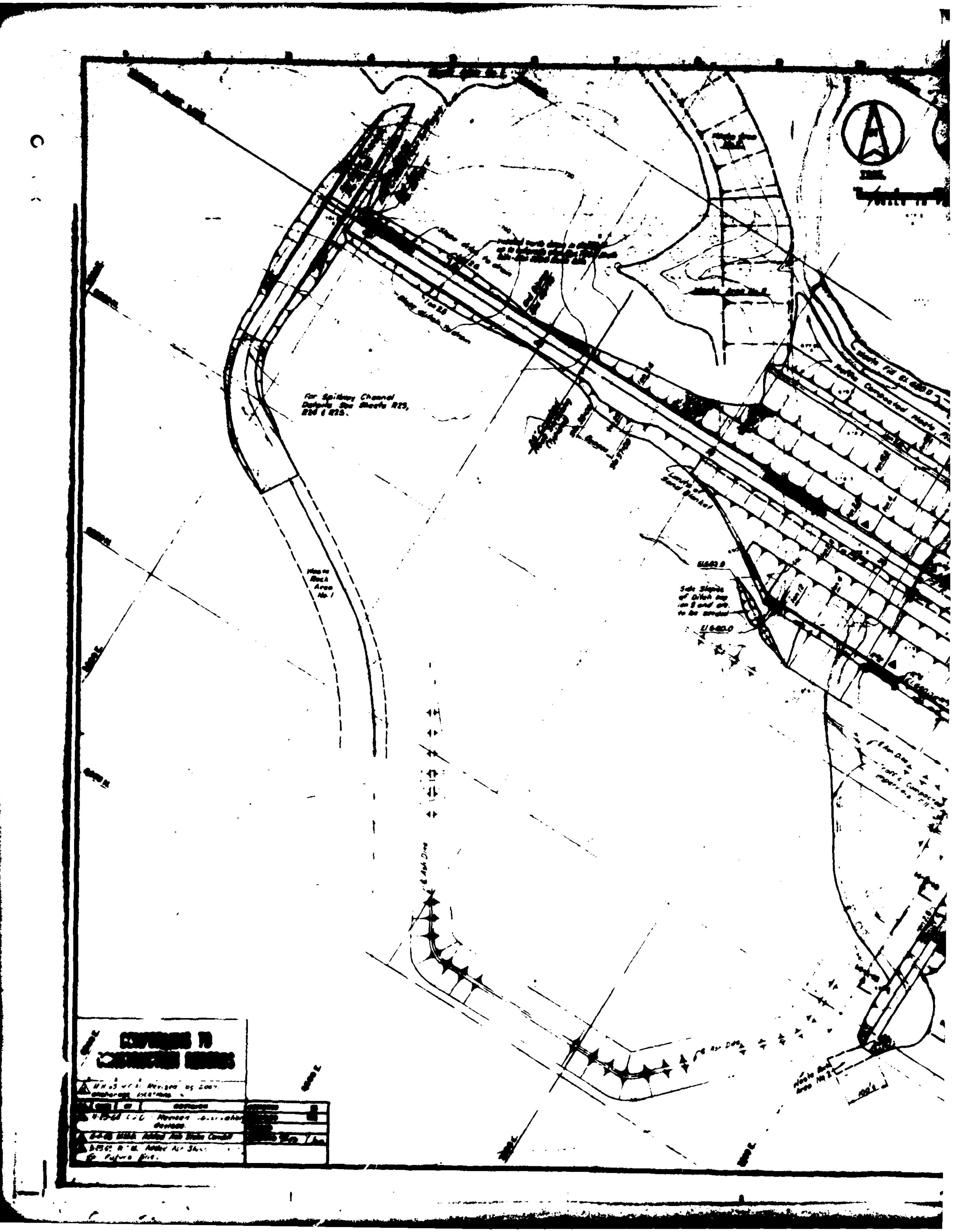
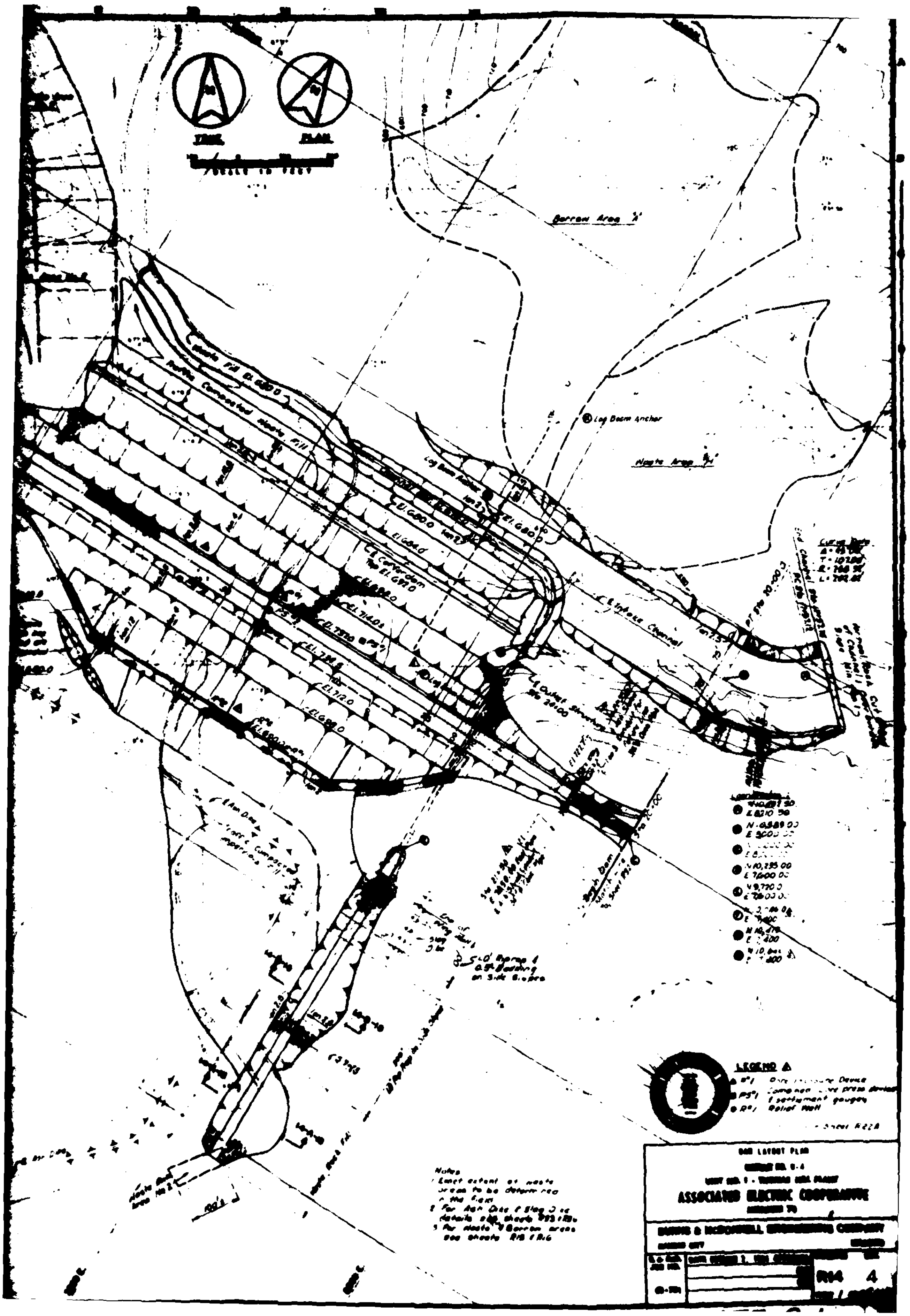


PHOTO NO. 40 - OVERVIEW TAKEN FROM LEFT ABUTMENT ROADWAY INTO POWER PLANT

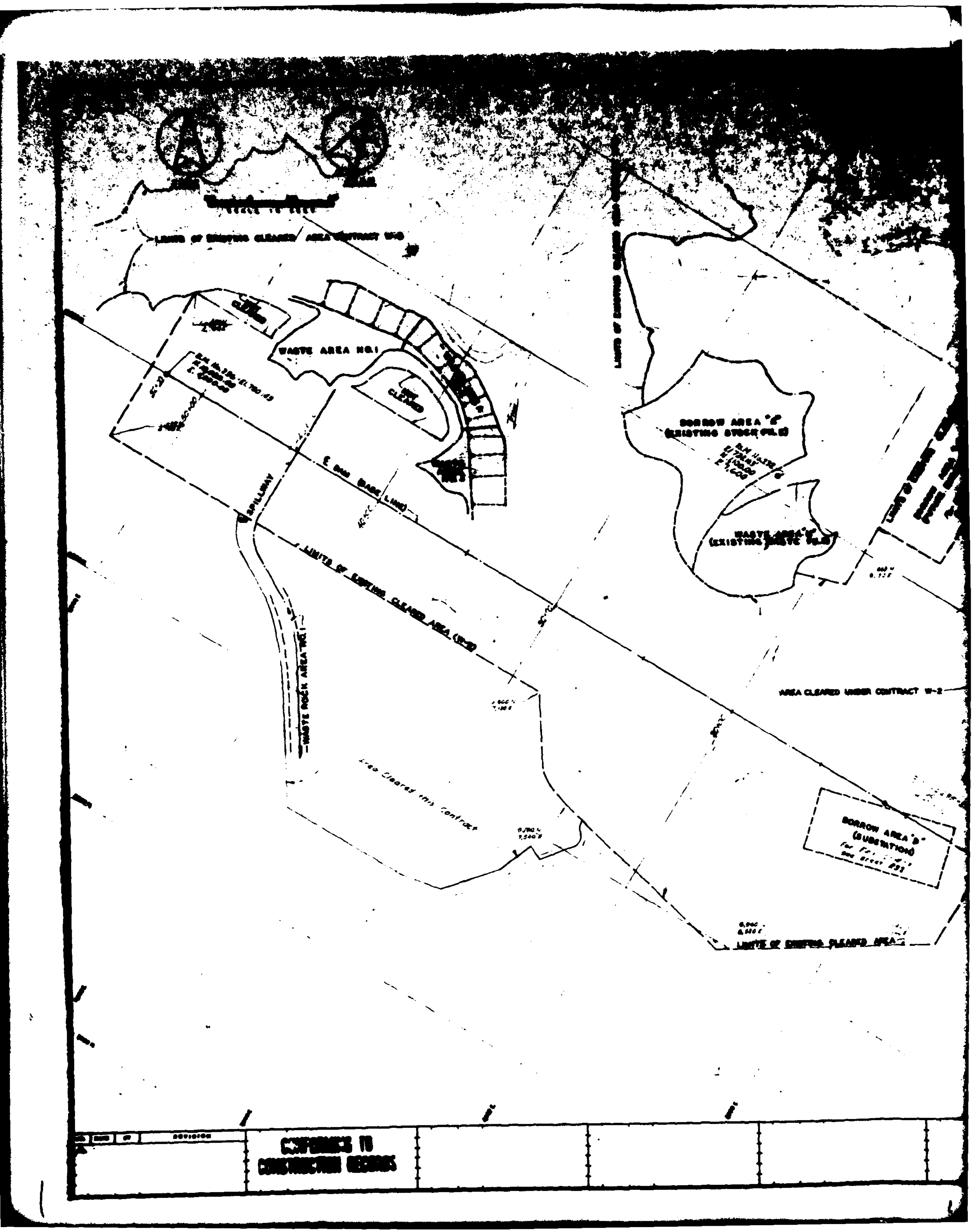
APPENDIX C
PROJECT PLATES

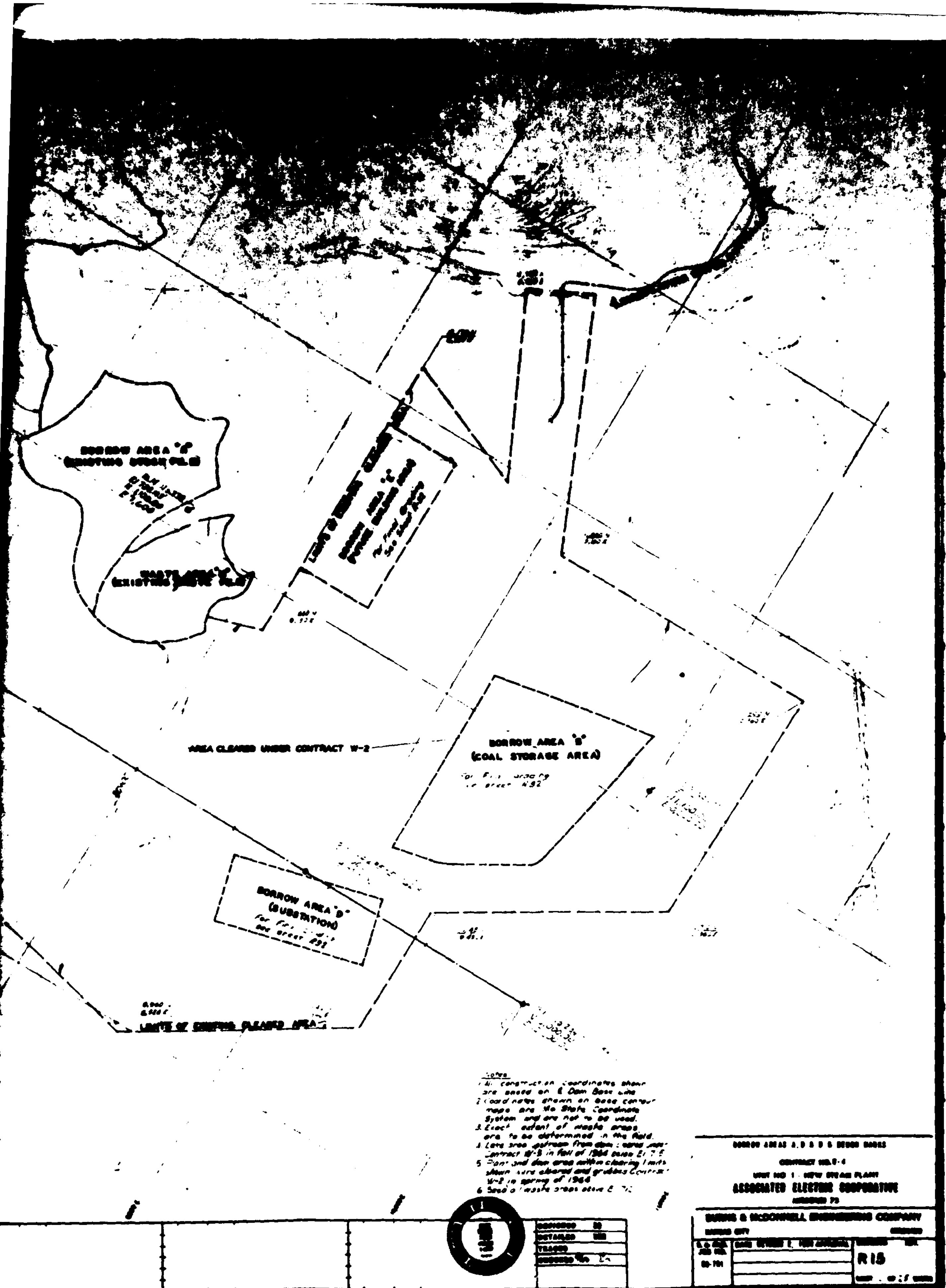


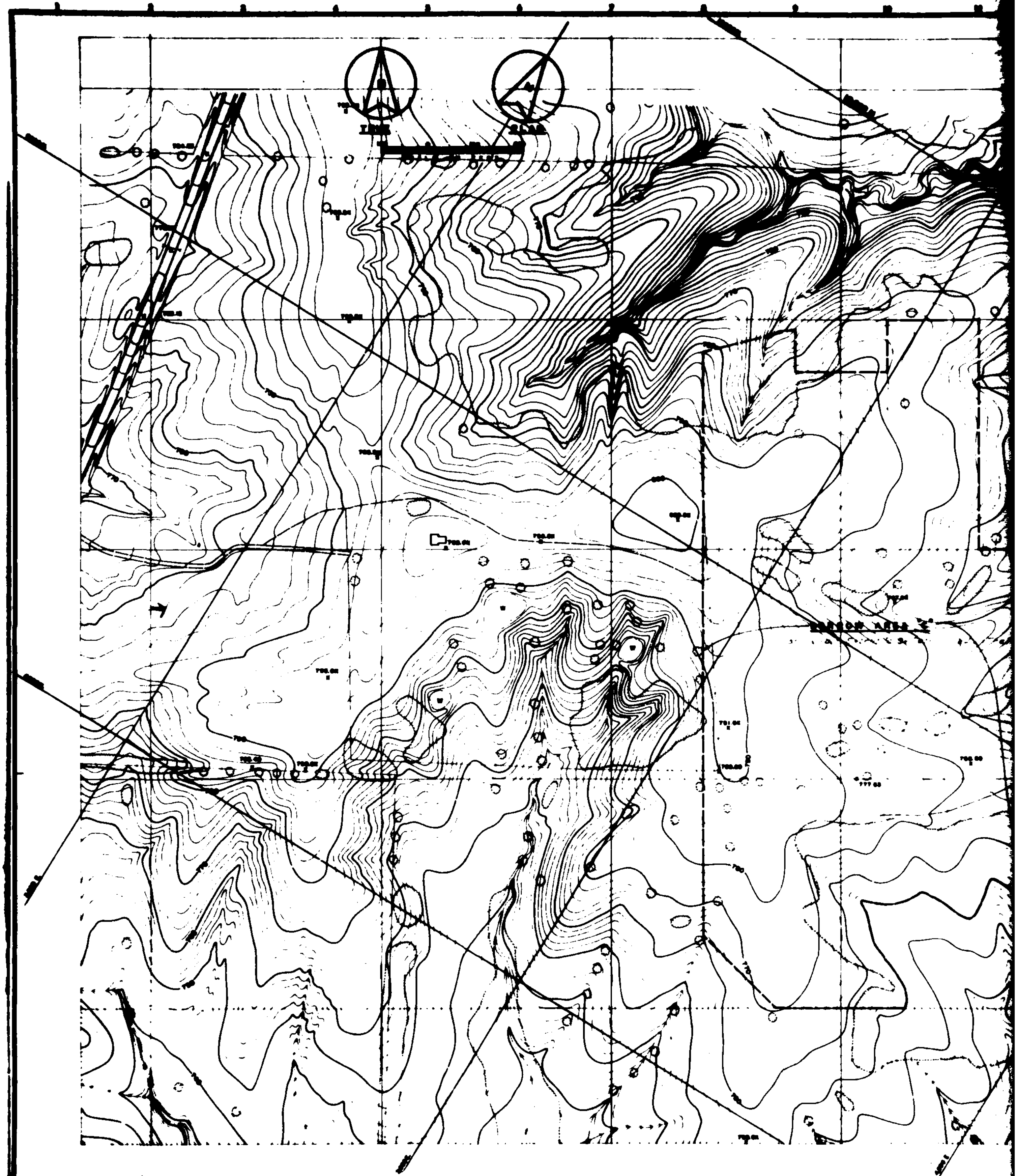
For Spillway Channel
Side Slopes of Ditch
El 6610.0
Waste Rock Area No. 1
Compacted Waste Fill



Borrow Area "A"
Waste Area "A"
Log Boom Anchor
Intake Channel
Outlet Structure
Relief Well
LEGEND
DAM LAYOUT PLAN
ASSOCIATED ELECTRIC COOPERATIVE
R14
4

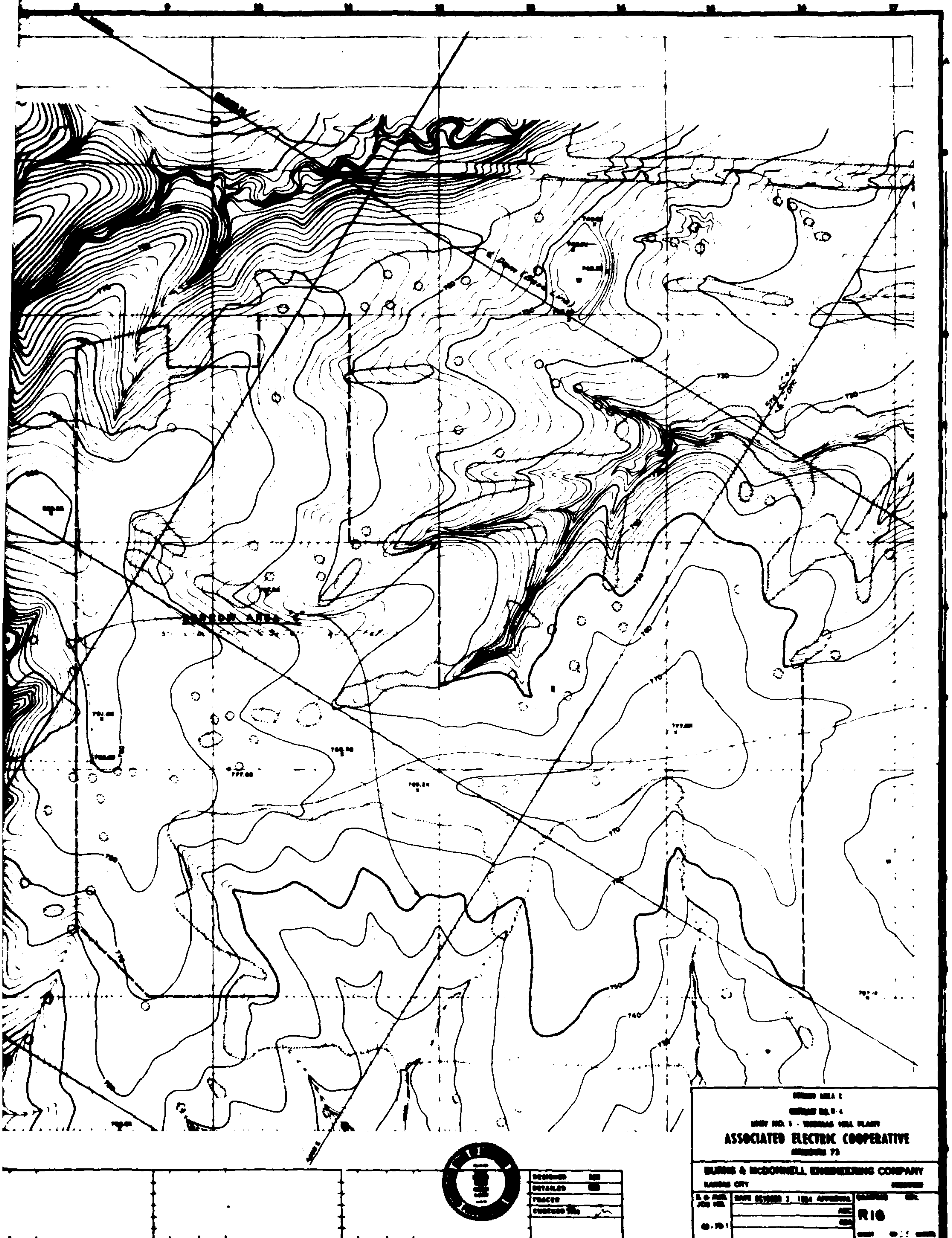

LIMITS OF EXISTING CLEARED AREA
WASTE AREA NO. 1
CLEARED
BORROW AREA "E"
(EXISTING STOCK PILE)
WASTE AREA "H"
(EXISTING WASTE PILE)
SPILLWAY
℄ DAM BASE LINE
WASTE ROCK AREA NO. 1
LIMITS OF EXISTING CLEARED AREA
AREA CLEARED UNDER CONTRACT W-2
Area Cleared this Contract
BORROW AREA "D"
(SUBSTATION)
LIMITS OF EXISTING CLEARED AREA
REVISION
CONFORMANCE TO
CONSTRUCTION RECORDS


BORROW AREA "B"
(COAL STORAGE AREA)
BORROW AREA "D"
(SUBSTATION)
AREA CLEARED UNDER CONTRACT W-2
LIMITS OF EXISTING CLEARED AREA
Notes
1. All construction coordinates shown are based on Ⓒ Dam Base Line
2. Coordinates shown on base contour maps are Mo State Coordinate System and are not to be used.
3. Exact extent of waste areas are to be determined in the field.
4. Lake area upstream from dam cleared under Contract W-3 in fall of 1964 below El 7'5
5. Plant and dam area within clearing limits shown were cleared and grubbed Contract W-2 in spring of 1964
ASSOCIATED ELECTRIC COOPERATIVE
BURNS & McDONNELL ENGINEERING COMPANY
R15
PLATE C-2



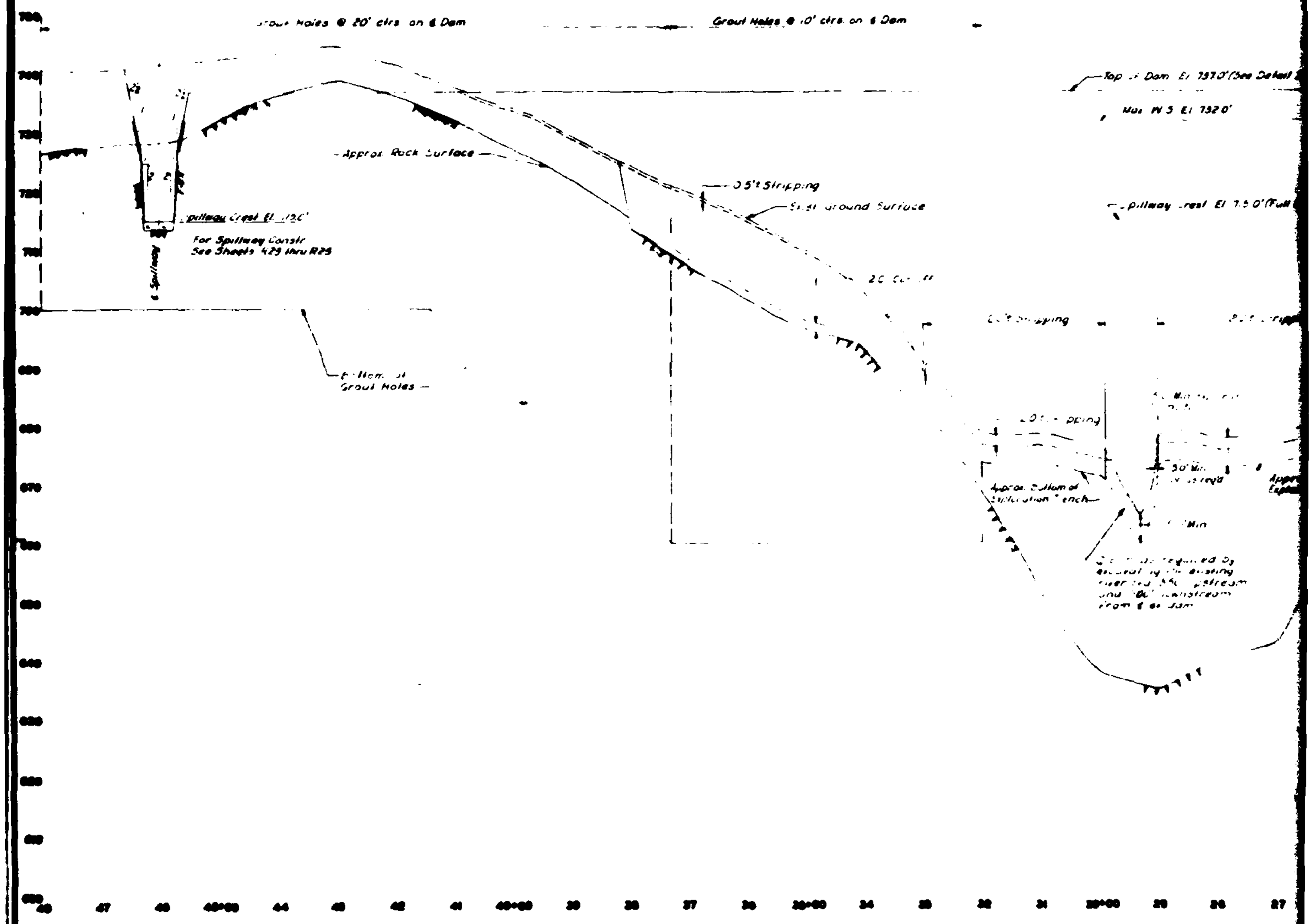
NO.	DATE	BY	REVISION

CONFORMING TO
CONSTRUCTION RECORDS



ASSOCIATED ELECTRIC COOPERATIVE
BURNS & McDONNELL ENGINEERING COMPANY
R10

PLATE C-3



PROFILE-¢ DAM
(Looking Upstream)

HOR.

VERT.

CONFORMING TO CONSTRUCTION RECORDS

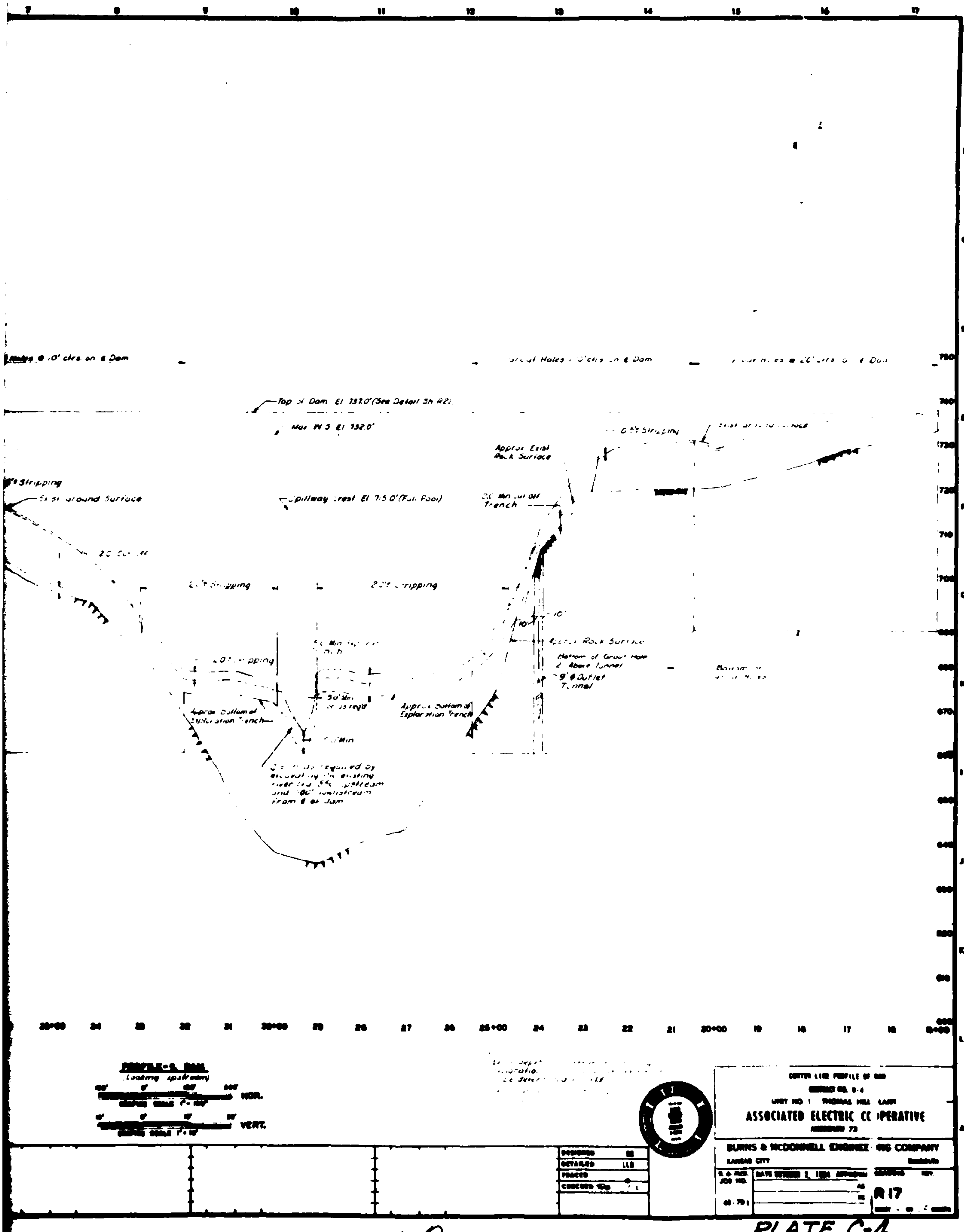
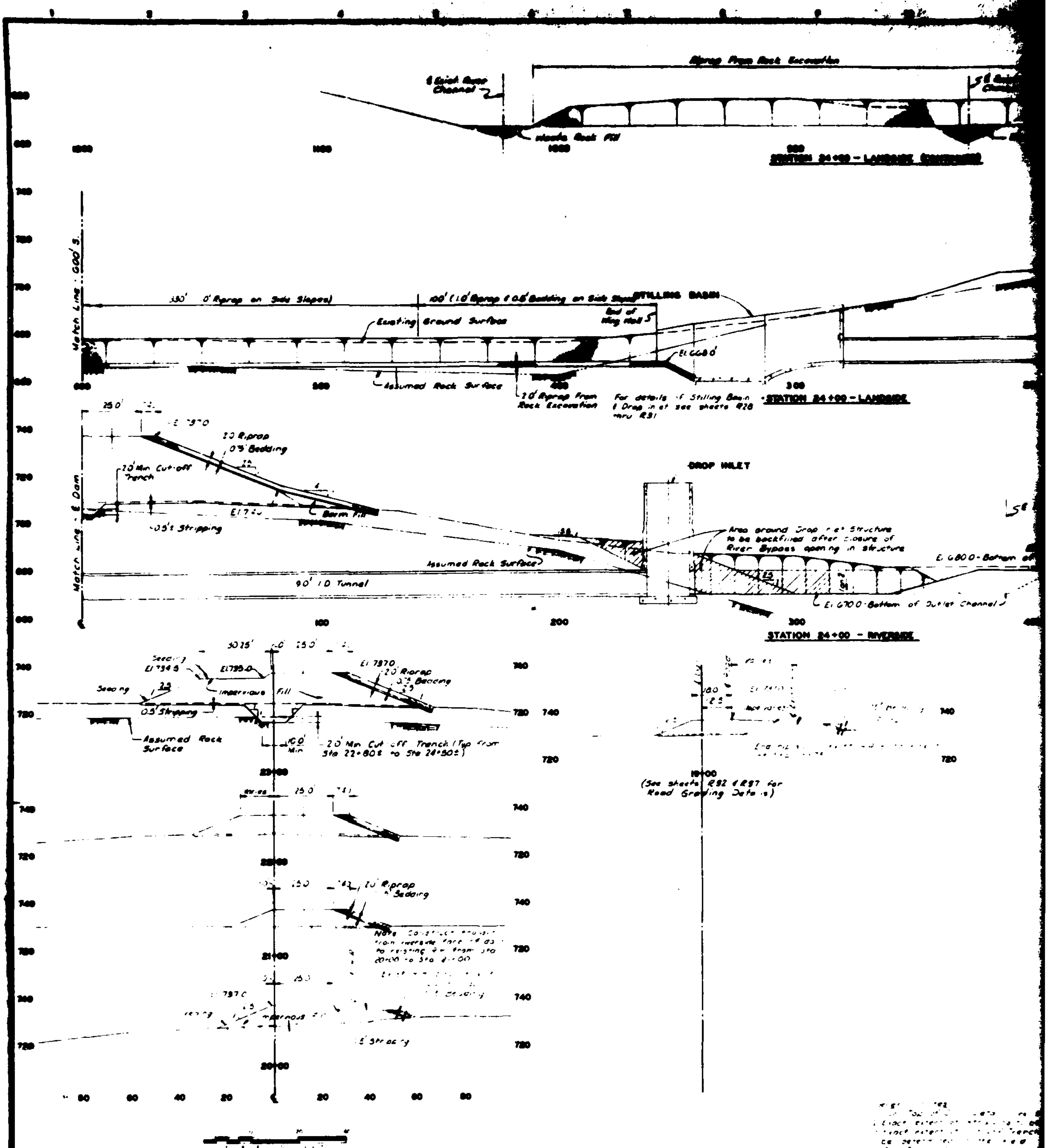
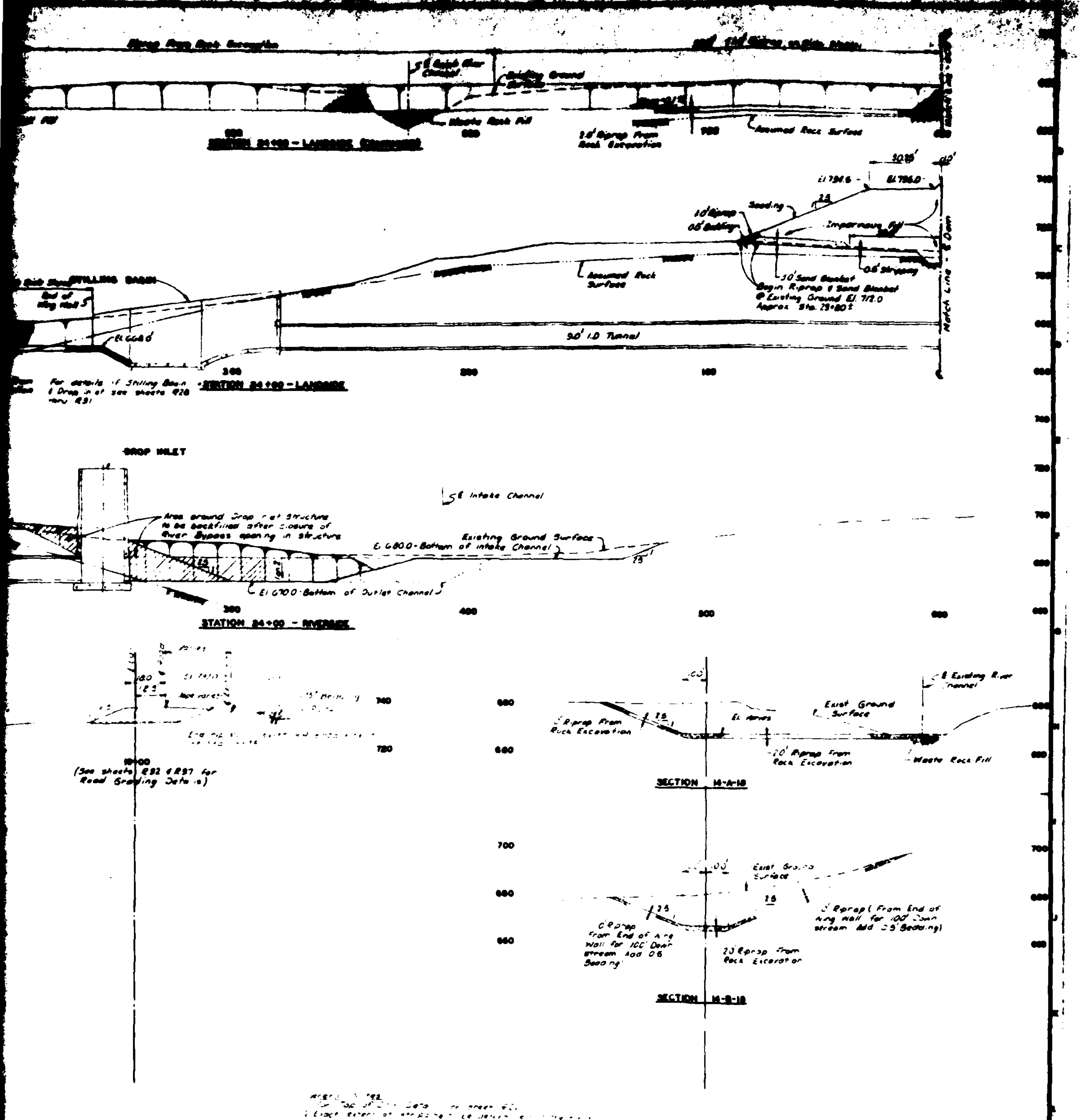

Holes @ 10' ctrs on ℄ Dam
Grout Holes @ 10' ctrs on ℄ Dam
Top of Dam El 737.0' (See Detail Sh R22)
Max W.S. El 732.0'
Approx Exist Rock Surface
Exist Ground Surface
Stripping
Spillway Crest El 715.0' (Full Pool)
2.0' Min cut off Trench
2.0' Stripping
2.0' Stripping
Approx Rock Surface
Bottom of Grout Hole 2' Above Tunnel
9' ø Outlet Tunnel
Approx Bottom of Exploration Trench
Approx Bottom of Exploration Trench
5.0' Min
PROFILE-℄ DAM
(Looking upstream)
HOR.
VERT.
CENTER LINE PROFILE OF DAM
UNIT NO 1 THOMAS HILL
ASSOCIATED ELECTRIC COOPERATIVE
BURNS & McDONNELL ENGINEERING COMPANY
KANSAS CITY
DESIGNED
DETAILED
TRACED
CHECKED
R 17

PLATE C-4



CONFORMING TO
CONSTRUCTION RECORDS



DETAILED CROSS SECTIONS AND STA 20+00 TO STA 24+00

CONTRACT NO. 9-4

UNIT NO. 1 THOMAS HILL PLANT

ASSOCIATED ELECTRIC COOPERATIVE

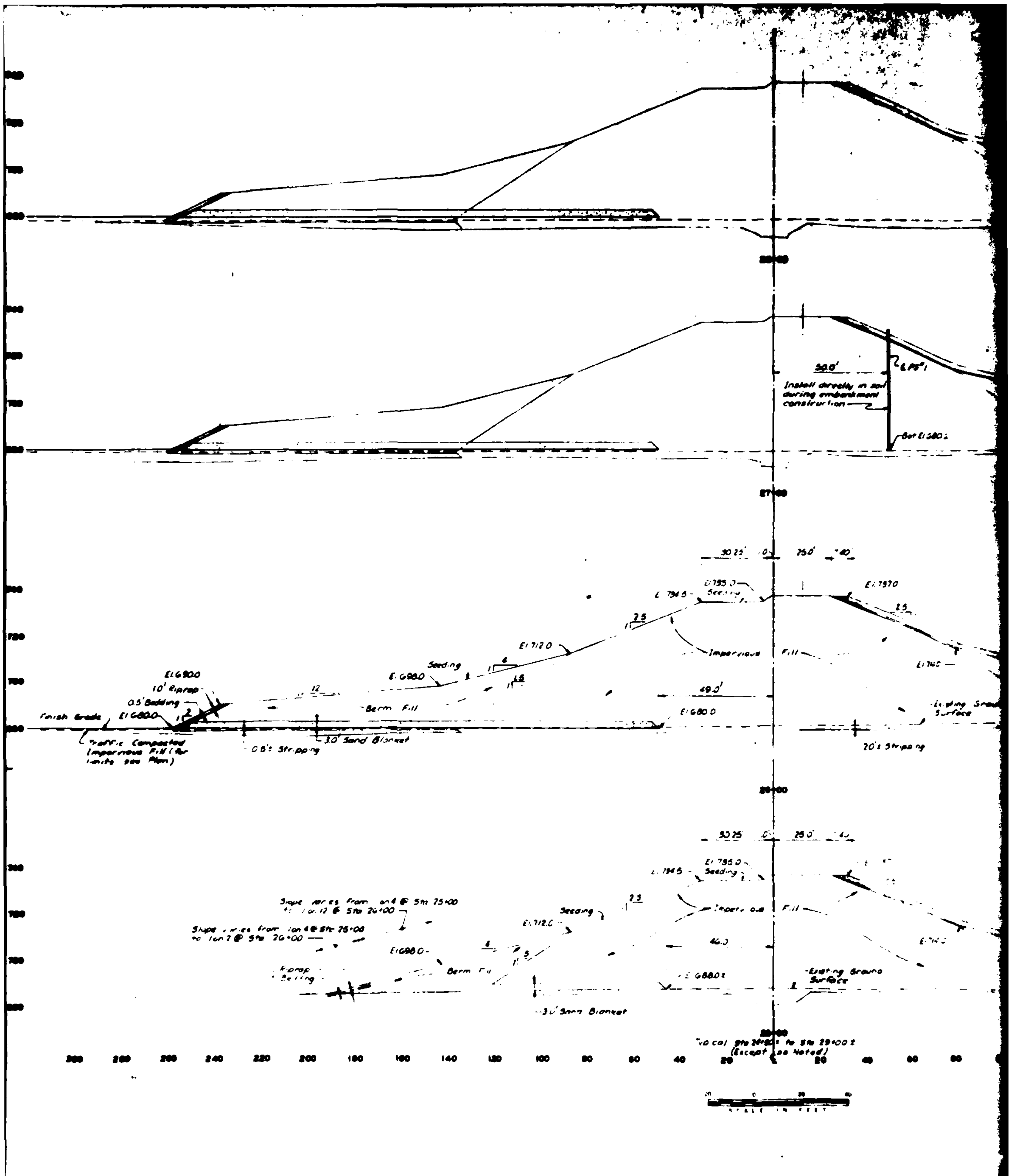
BURNS & McDONNELL ENGINEERING COMPANY

KANSAS CITY

DESIGNED	
DETAILED	
TRACED	
CHECKED	

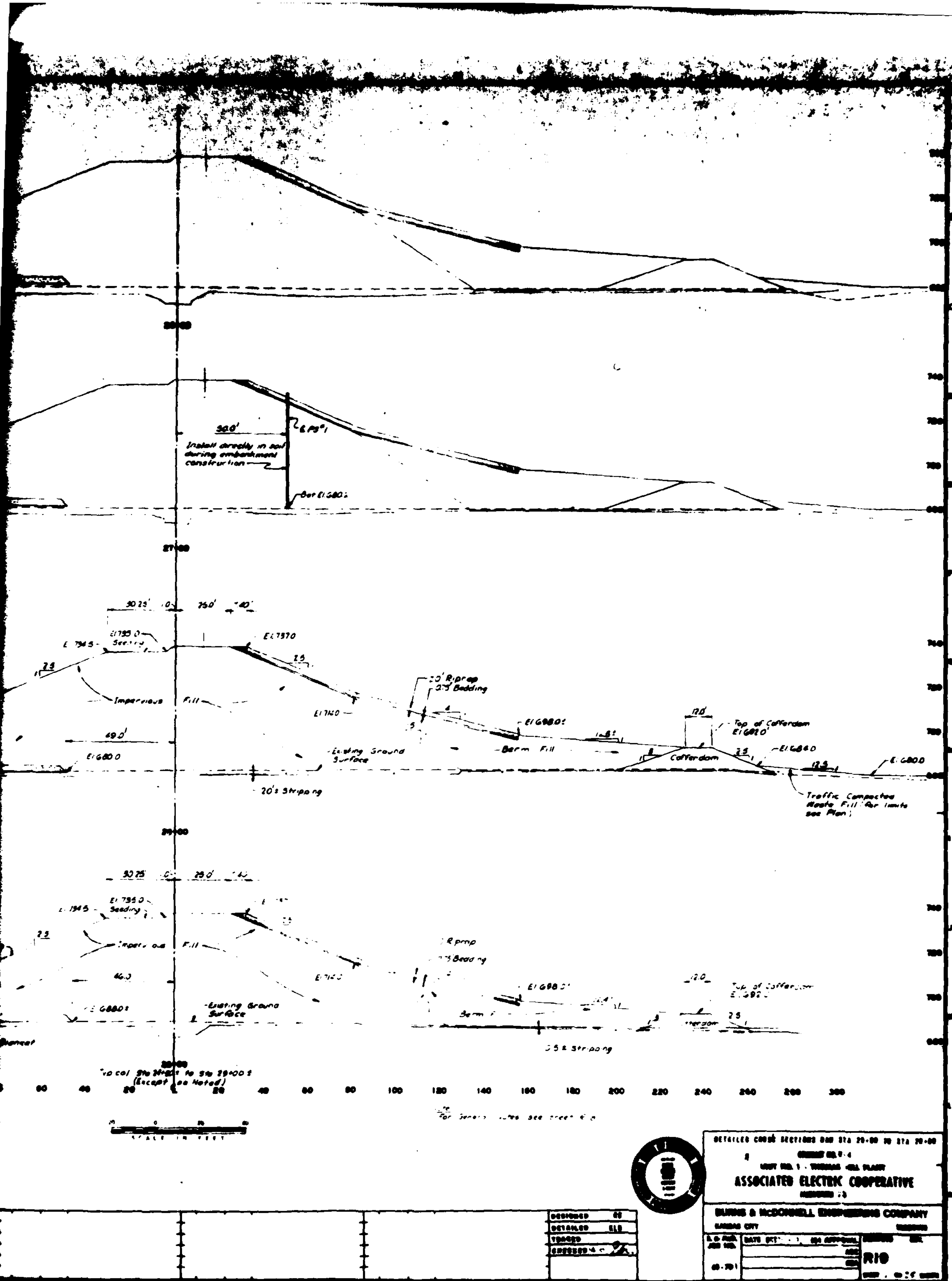
R10

PLATE C-5



REVISION

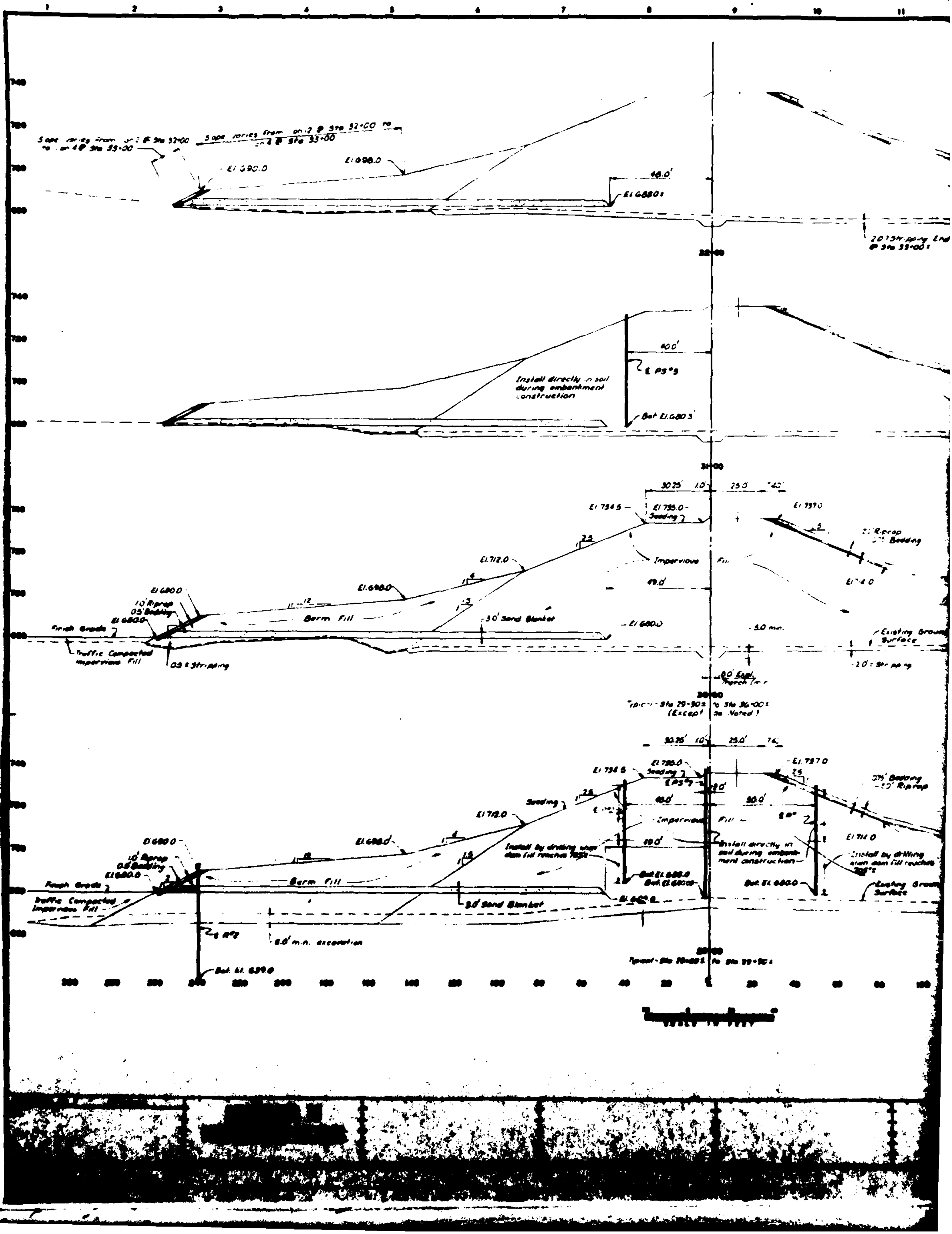
CONFORMING TO
CONSTRUCTION RECORDS



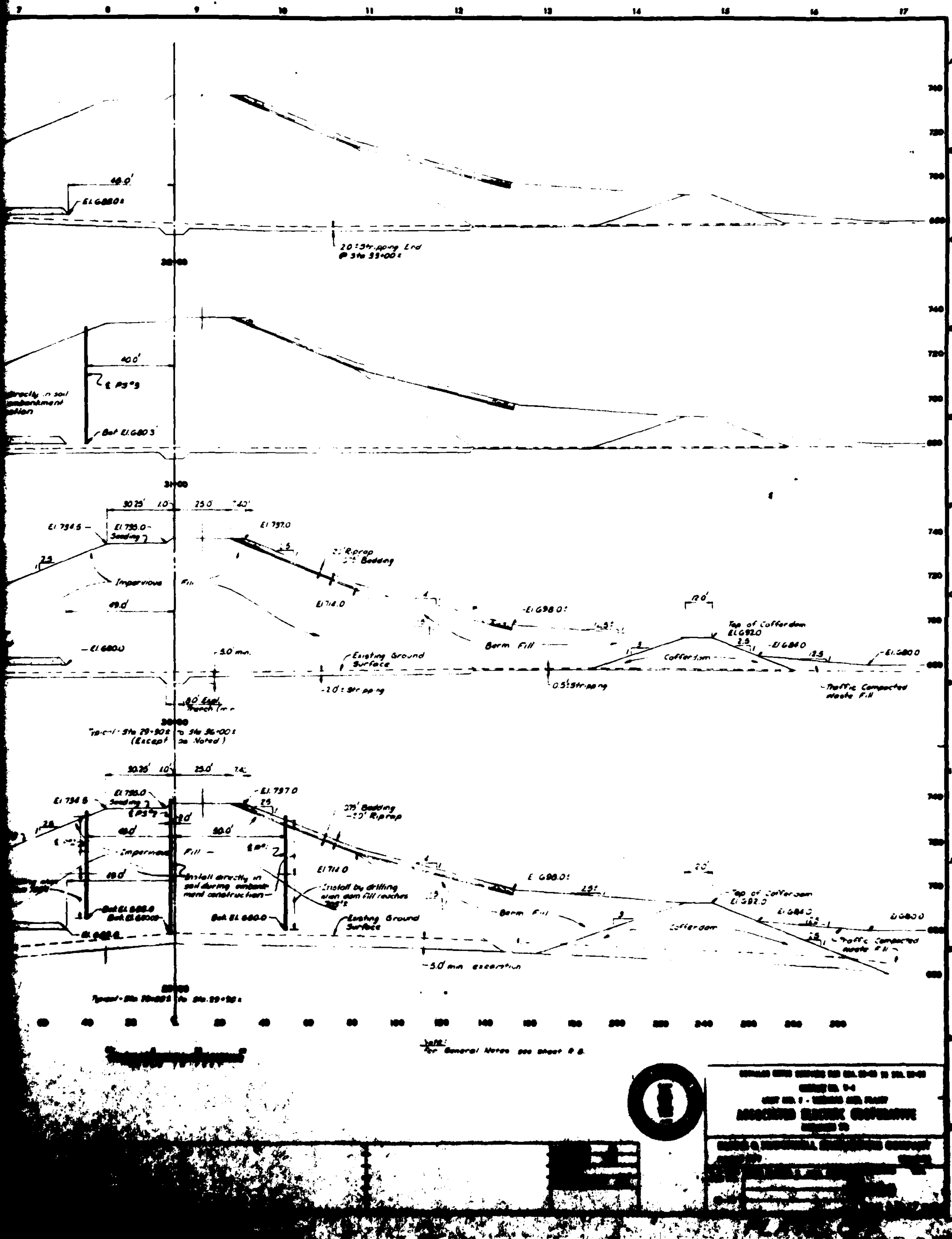
Install directly in soil during embankment construction
Bot El 680±
El 735.0 Seeding
El 737.0
Impervious Fill
El 714.0
2.0' Riprap
2.5' Bedding
El 698.0±
Berm Fill
Top of Cofferdam El 692.0'
Cofferdam
El 684.0
El 680.0
El 680.0
Existing Ground Surface
2.0'± Stripping
Traffic Compacted Waste Fill (for limits see Plan)
Existing Ground Surface
Typical Sta 24+00 to Sta 29+00± (Except as Noted)
SCALE IN FEET
ASSOCIATED ELECTRIC COOPERATIVE
BURNS & McDONNELL ENGINEERING COMPANY
R10

PLATE C-6

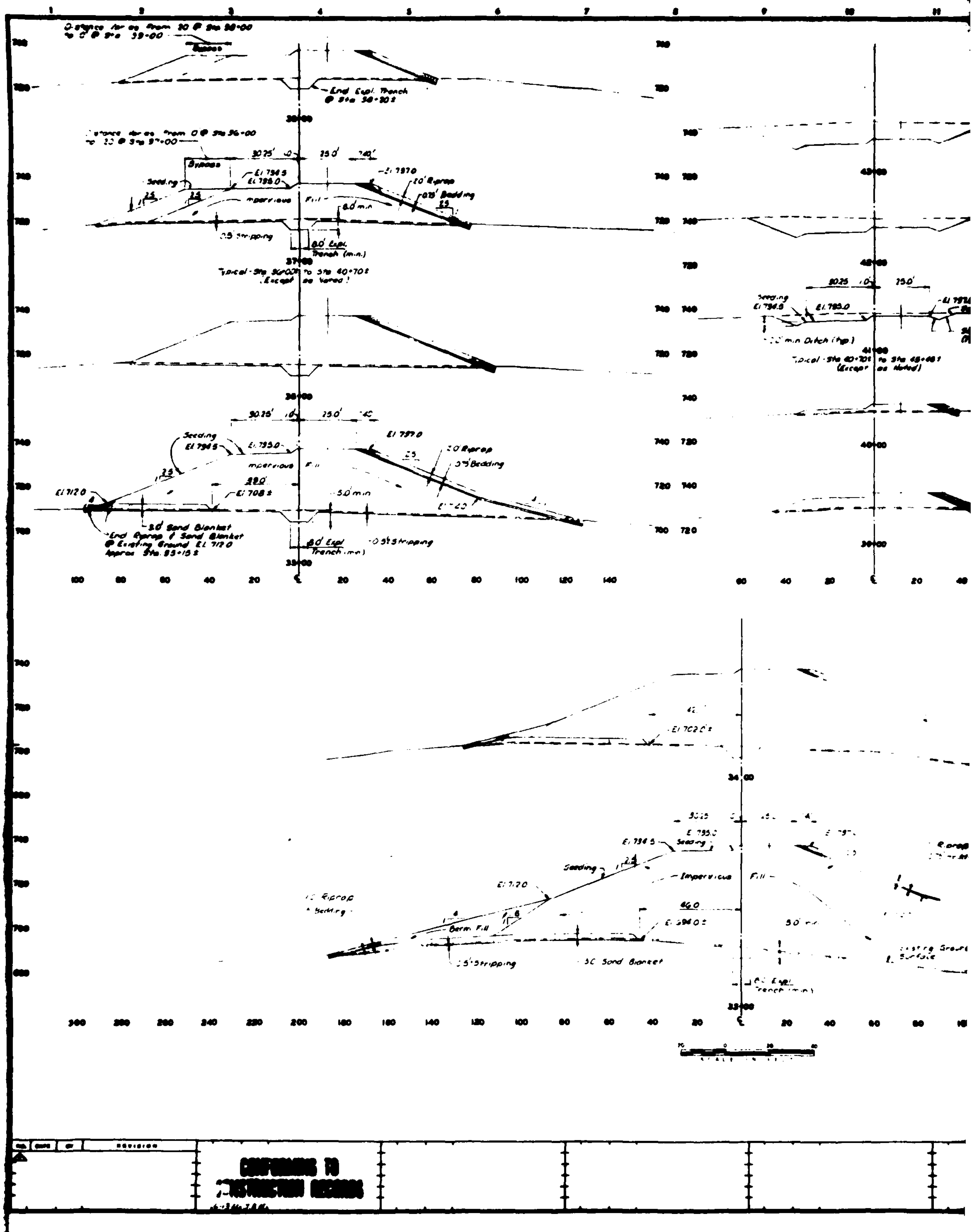
1 2



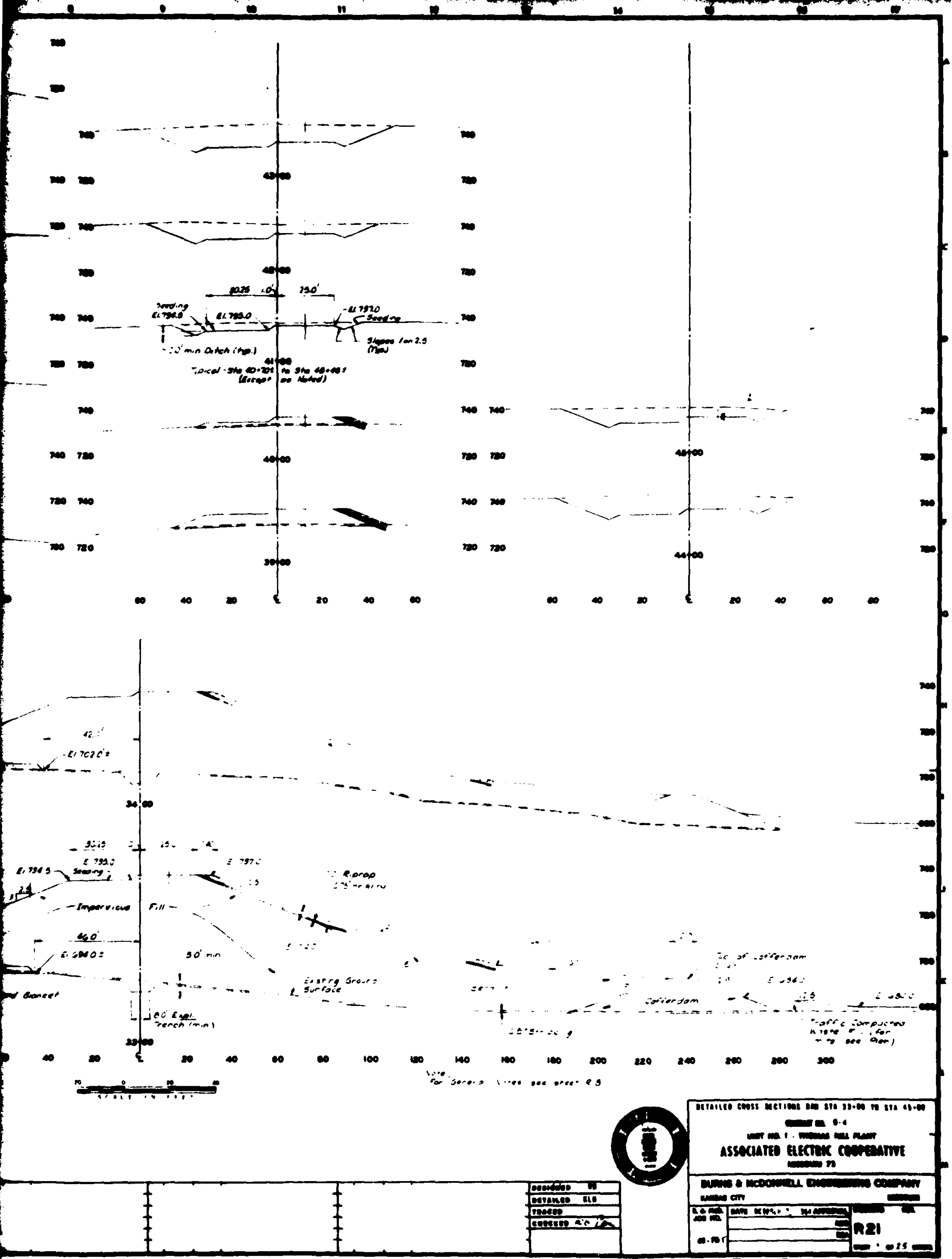
Slope varies from on 2 @ Sta 32+00 to on 4 @ Sta 33+00
Slope varies from on 12 @ Sta 32+00 to on 2 @ Sta 33+00
El 690.0
El 698.0
48.0'
El 680.0±
2.0'± Stripping End @ Sta 33+00±
32+00
40.0'
℄ PS #3
Install directly in soil during embankment construction
Bot El 680.5'
31+00
30.25' 1.0' 25.0' 14.0'
El 734.5
El 735.0
Seeding
El 737.0
2.5
2.0' Riprap
0.75' Bedding
El 712.0
Impervious Fill
El 714.0
49.0'
El 698.0
El 680.0
1.0' Riprap
0.5' Bedding
El 680.0
Berm Fill
3.0' Sand Blanket
El 680.0
5.0 min.
Finish Grade
Existing Ground Surface
Traffic Compacted Impervious Fill
0.5'± Stripping
2.0'± Stripping
8.0' Expl. Trench (min)
30+00
Typical - Sta 29+90± to Sta 36+00± (Except as Noted)
30.25' 1.0' 25.0' 14.0'
El 734.5
El 735.0
Seeding
El 737.0
℄ PS #2
0.75' Bedding
2.0' Riprap
Seeding
40.0'
50.0'
El 712.0
Impervious Fill
El 714.0
El 698.0
49.0'
Install by drilling when dam fill reaches 705'±
Install directly in soil during embankment construction
Install by drilling when dam fill reaches 705'±
1.0' Riprap
0.5' Bedding
El 680.0
Berm Fill
Bot El 688.0
Bot El 680.0
Bot El 680.0
Finish Grade
Traffic Compacted Impervious Fill
3.0' Sand Blanket
El 680.0
Existing Ground Surface
℄ R #2
8.0' min. excavation
29+00
Typical - Sta 28+65± to Sta 29+90±
Bot El 659.0
740
720
700
680
660
260 240 220 200 180 160 140 120 100 80 60 40 20 0 20 40 60 80 100
1 2 3 4 5 6 7 8 9 10 11



40.0'
El. 680.0±
2.0' Stripping End @ Sta 33+00±
30+00
40.0'
℄ PS#9
Install directly in soil during embankment construction
Bot. El. 680.3'
31+00
30.25'
1.0'
25.0'
7.40'
El. 734.5
El. 735.0
Seeding
El. 737.0
2.5
2.0' Riprap
0.75' Bedding
Impervious Fill
49.0'
El. 714.0
El. 698.0±
Berm Fill
El. 680.0
5.0' min.
Existing Ground Surface
2.0' Stripping
0.5' Stripping
8.0' Expl. Trench
12.0'
Top of Cofferdam El. 692.0
El. 684.0
El. 680.0
Cofferdam
Traffic Compacted Waste Fill
Typical - Sta 29+90± to Sta 36+00± (Except as Noted)
30.25'
1.0'
25.0'
7.4'
El. 734.5
El. 735.0
Seeding
℄ PS#9
El. 737.0
0.75' Bedding
2.0' Riprap
Impervious Fill
Install directly in soil during embankment construction
Install by drilling when dam fill reaches
El. 714.0
El. 698.0±
Bot. El. 680.0
Existing Ground Surface
Berm Fill
12.0'
Top of Cofferdam El. 692.0
El. 684.0
El. 680.0
Cofferdam
Traffic Compacted Waste Fill
5.0' min. excavation
Typical - Sta 29+90± to Sta 29+90±
740
720
700
680
660
Note:
For General Notes see sheet R 8.
ASSOCIATED ELECTRIC COOPERATIVE

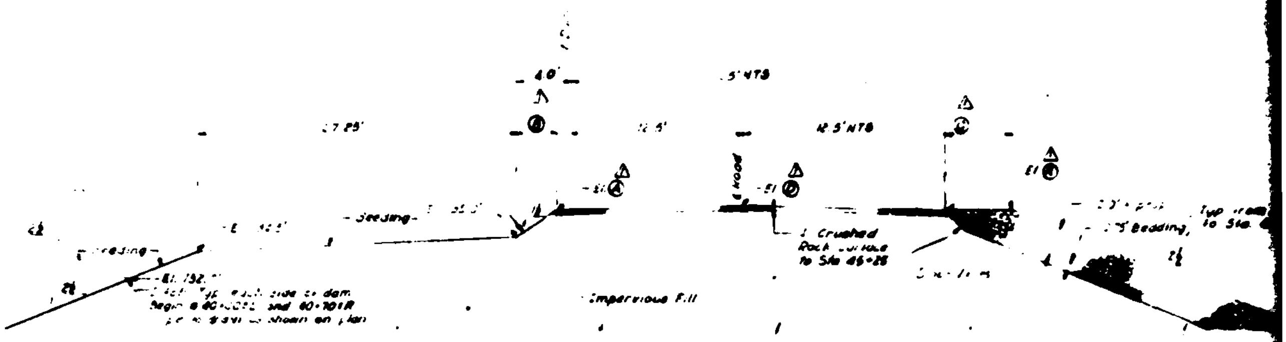


Distance for as from 30 @ Sta 38+00 to 0 @ Sta 39+00
Bypass
End Expl. Trench @ Sta 38+30±
38+00
Bypass
Seeding
El 794.5
El 795.0
El 797.0
2.0' Riprap
0.75' Bedding
Impervious Fill
8.0 min
0.5' Stripping
8.0' Expl. Trench (min.)
37+00
Typical - Sta 36+00 to Sta 40+70± (Except as Noted)
36+00
30.25'
25.0'
Seeding
El 794.5
El 795.0
El 797.0
2.0' Riprap
0.5' Bedding
Impervious Fill
El 712.0
El 708±
5.0' min
3.0' Sand Blanket
End Riprap & Sand Blanket @ Existing Ground El 712.0 Approx Sta 35+15±
8.0' Expl. Trench (min.)
0.5' Stripping
35+00
42+00
41+00
Seeding
El 794.5
El 795.0
2.0' min Ditch (typ.)
Typical - Sta 40+70± to Sta 48+46±
(Except as Noted)
40+00
39+00
34+00
El 702.0±
El 794.5
El 795.0
Seeding
Impervious Fill
El 712.0
2.0' Riprap
Bedding
Berm Fill
46.0
El 694.0±
5.0' min
0.5' Stripping
3.0' Sand Blanket
Existing Ground Surface
8.0' Expl. Trench (min.)
33+00
SCALE IN FEET
REVISION
CONFORMING TO CONSTRUCTION RECORDS



Typical - Sta 40+70± to Sta 48+46± (Except as Noted)
Seeding
EL 795.0
Slopes 1 on 2.5 (Typ)
Impervious Fill
Existing Ground Surface
Cofferdam
ASSOCIATED ELECTRIC COOPERATIVE
BURNS & McDONNELL ENGINEERING COMPANY
KANSAS CITY
R21

PLATE C-8



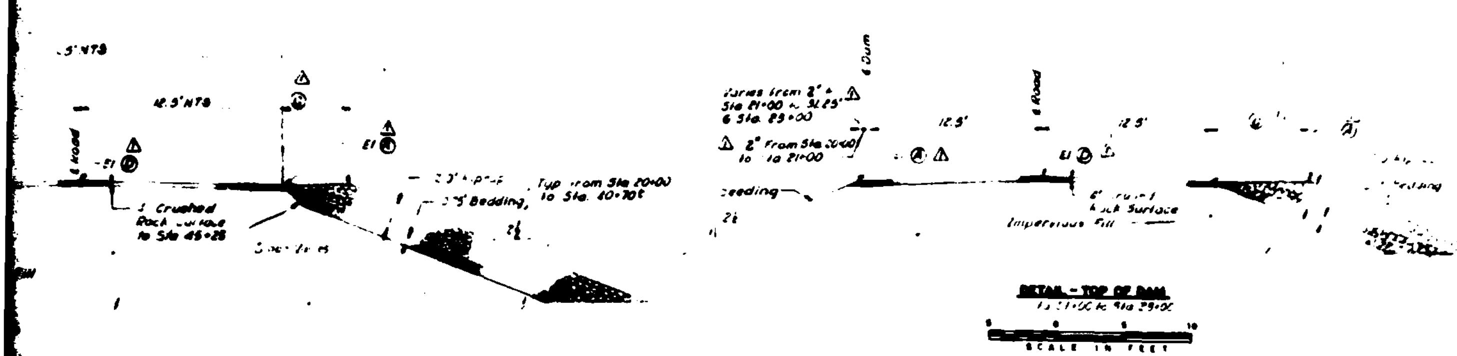
DETAIL - TOP OF DAM
Sta 23+00 to Spillway

SCALE IN FEET

DAM DIMENSIONS

STATION	A	B	C
20+00	[illegible]	-	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

Note: Elevations shown at points of vertical



DAM DIMENSIONS

STATION	A	B	C	D
20+00	[illegible]	–	[illegible]	732.67
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	4.10	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	6.37	[illegible]
40+70	[illegible]	[illegible]	7.40'	[illegible]

Note: Elevations shown in table are points of vertical intersection

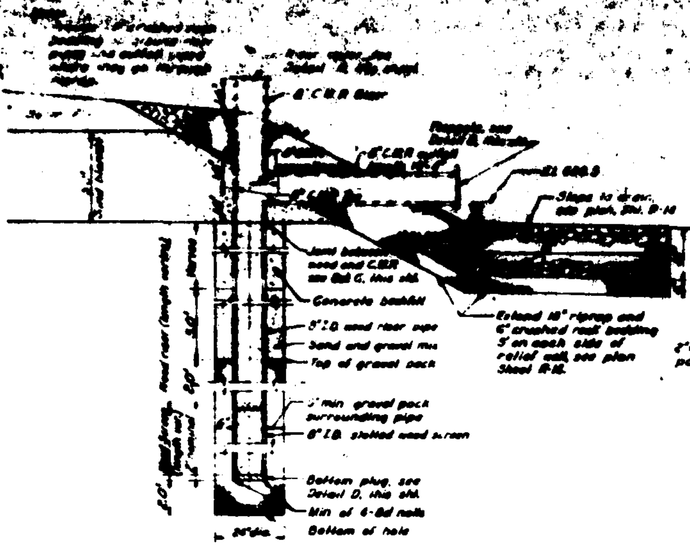
ASSOCIATED ELECTRIC COOPERATIVE

BURNS & McDONNELL ENGINEERING COMPANY

R22 - 1

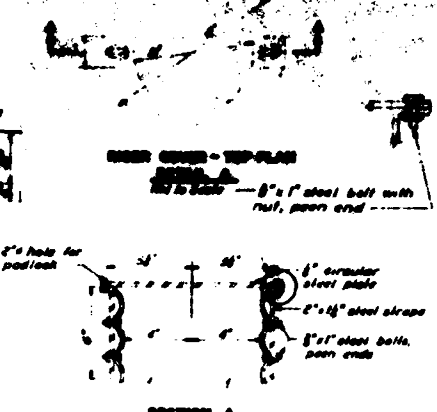
PLATE C-9

1 2

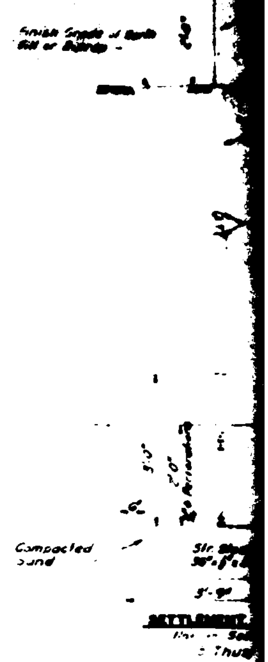


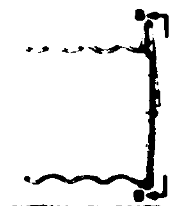
RELIEF WELL
(3 Thus)
Not to scale

Note:
The intent is to place the sand and gravel mix opposite the blank riser and the gravel pack opposite the screen.

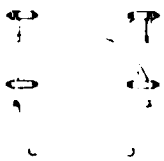


SECTION A
Not to Scale

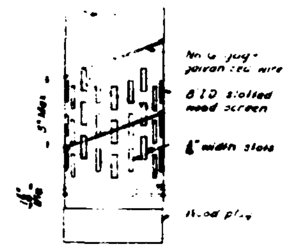




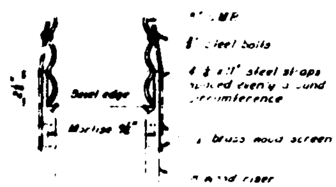
OUTFALL FLAPGATE
DETAIL B
Not to Scale



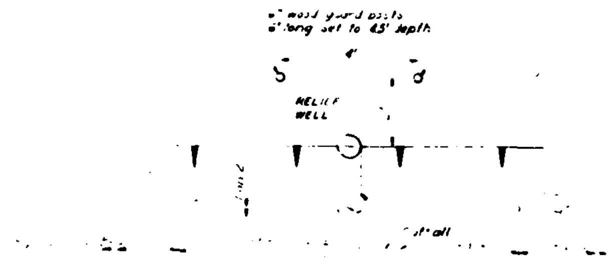
SECTION B



WOOD SCREEN WITH BOTTOM PLUG
DETAIL D



JOINT BETWEEN WOOD & C.M.P. PIPE
DETAIL C
Not to scale



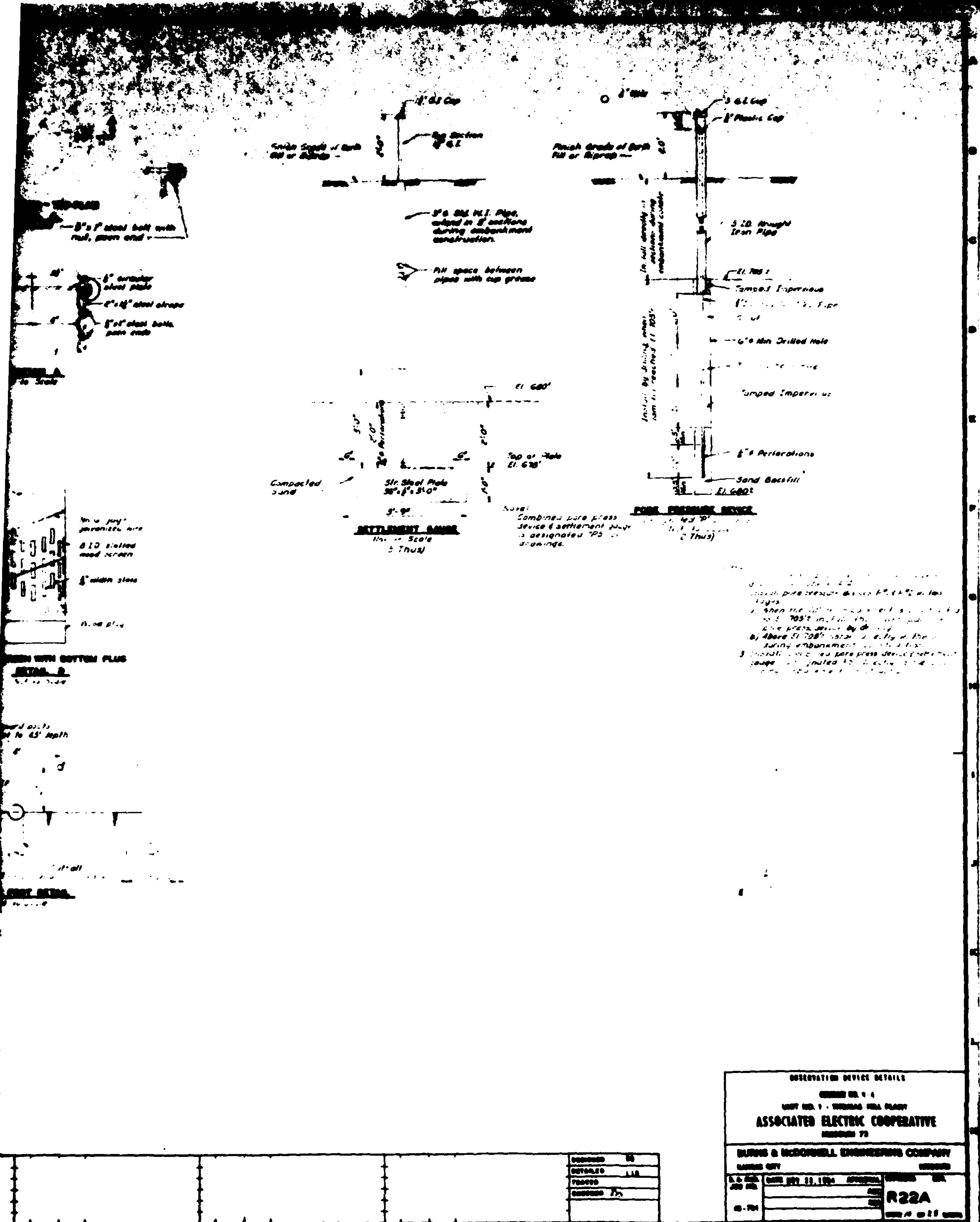
GUARD POST DETAIL

[illegible]	LOCATION	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	4. [illegible]	El. [illegible]	21'-0"	[illegible]
[illegible]	[illegible]	41' [illegible]	El. 638.0	21'-0"	19' [illegible]
[illegible]	[illegible]	3[illegible]	El. 648.0	18'-0"	11' 10"

WELL SCHEDULE

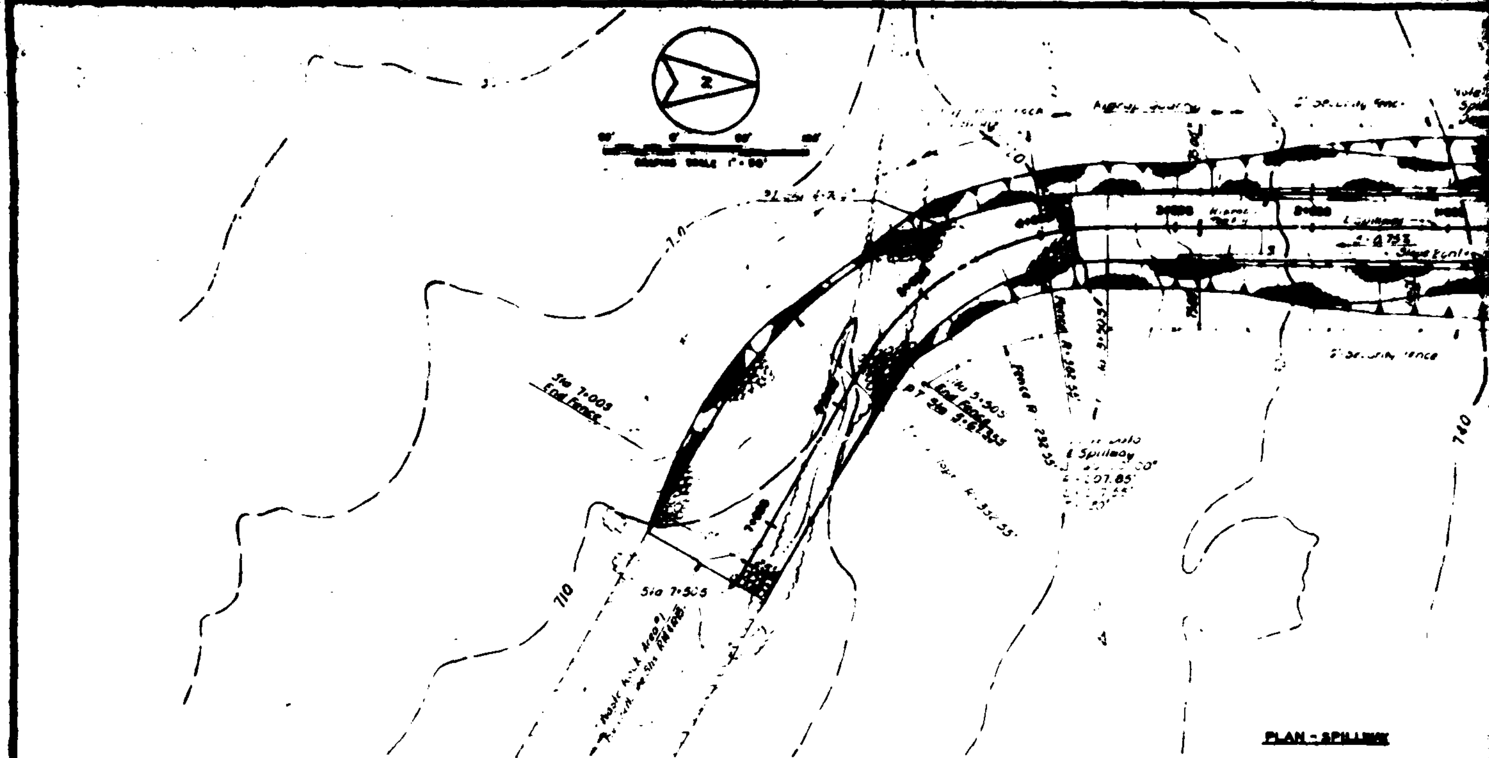
NO.	DATE	BY	REVISION

CONFORMING TO
CONSTRUCTION RECORDS

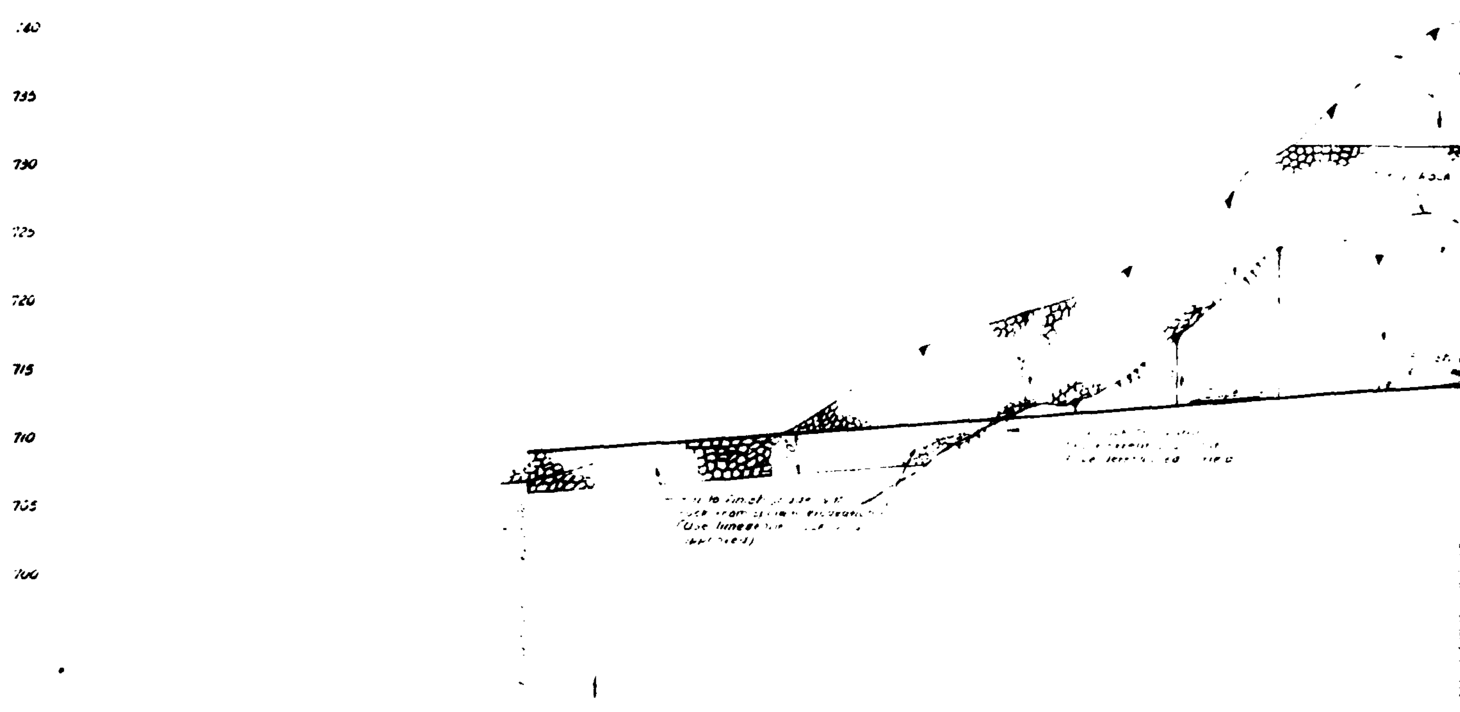


Finish Grade of Earth Fill or Riprap
Finish Grade of Earth Fill or Riprap
Fill space between pipes with cup grease
Iron Pipe
Tamped Impervious
Tamped Impervious
Perforations
Sand Backfill
El. 680'
Top of Plate
Compacted Sand
Stl. Steel Plate
SETTLEMENT GAUGE
PORE PRESSURE DEVICE
Combined pore press. device & settlement gauge is designated "PS" on drawings.
OBSERVATION DEVICE DETAILS
ASSOCIATED ELECTRIC COOPERATIVE
BURNS & McDONNELL ENGINEERING COMPANY
KANSAS CITY
R22A

PLATE C-10



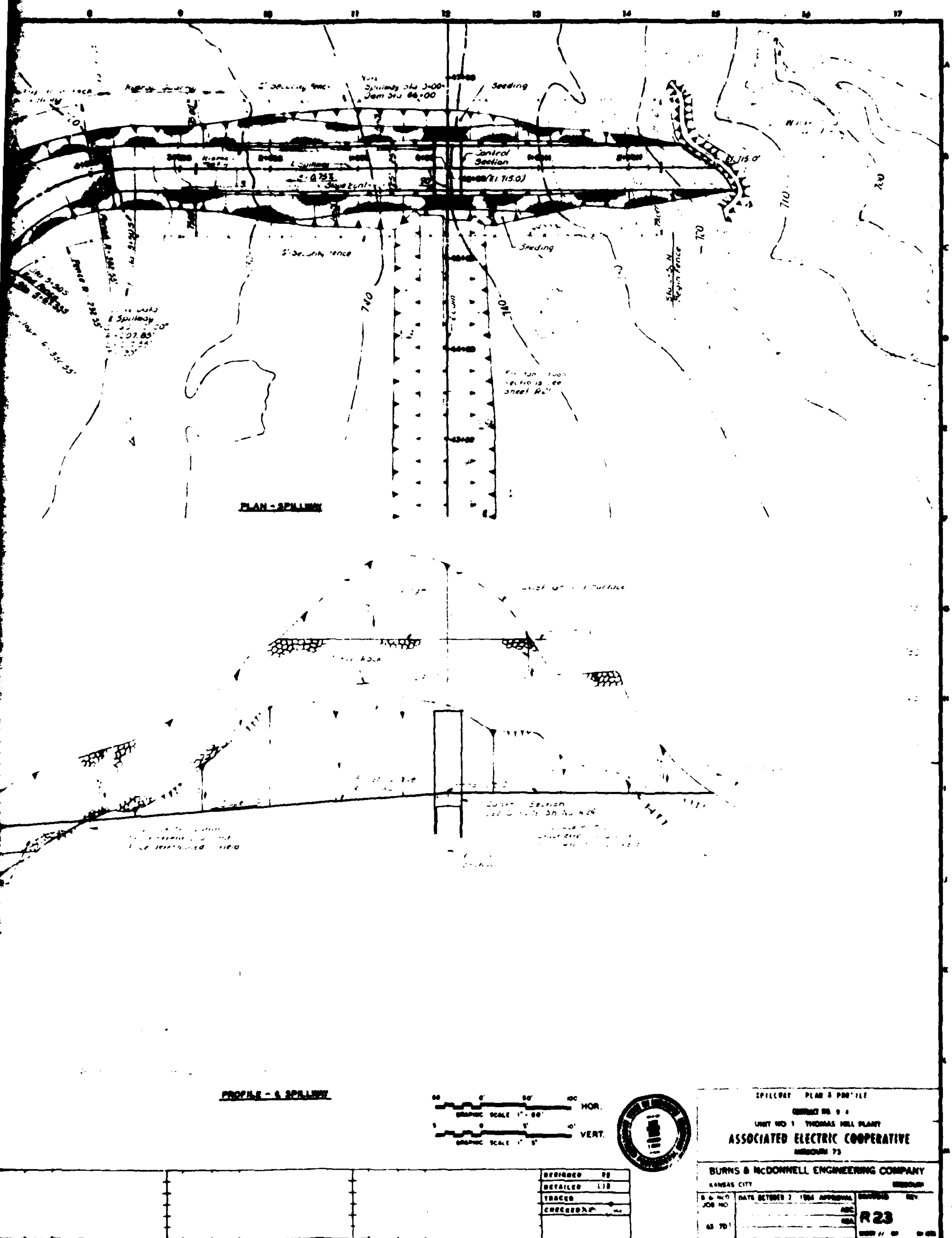
PLAN - SPILLWAY



PROFILE - ℄ SPILLWAY

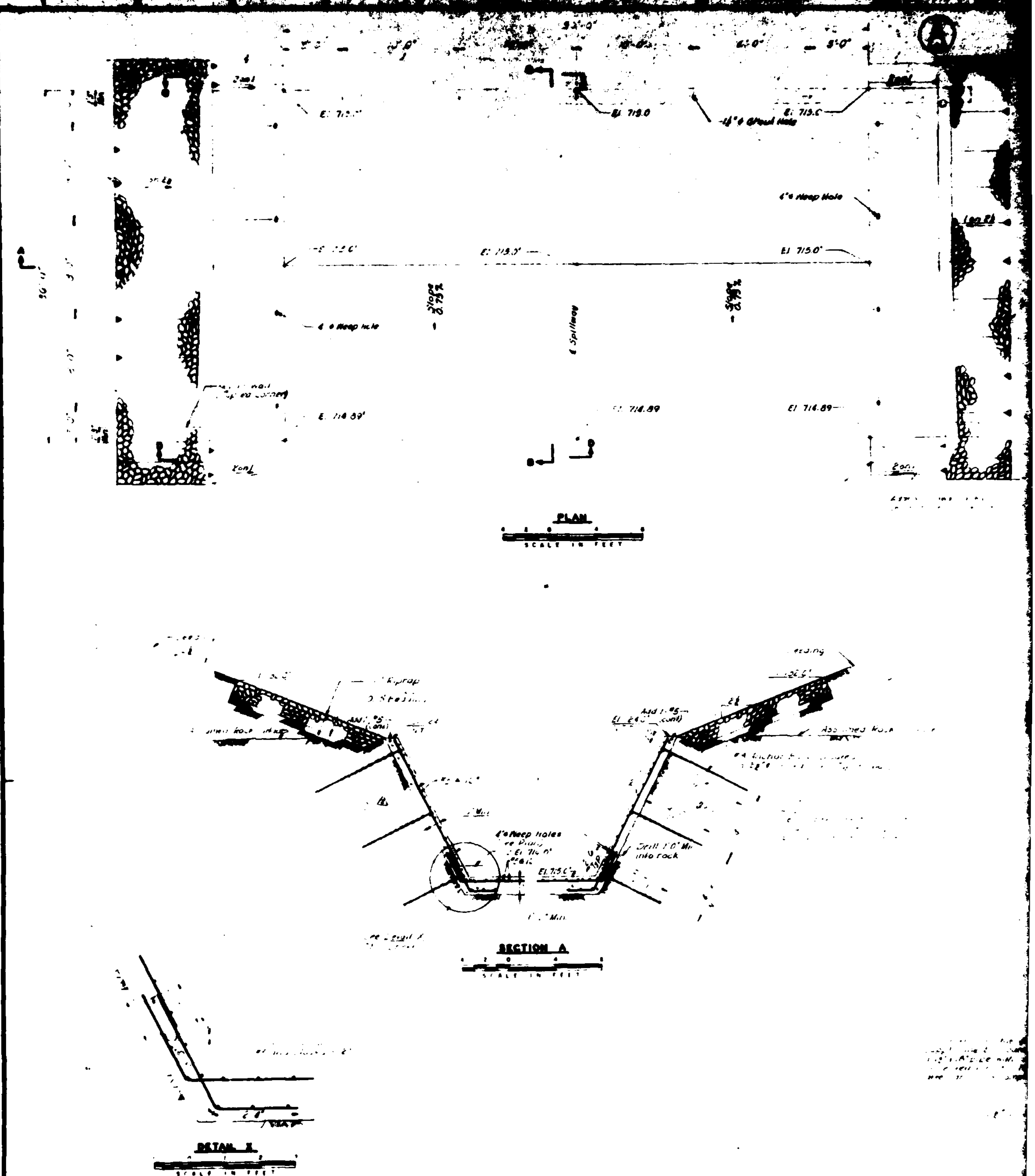
REVISION

CONFORMING TO
CONSTRUCTION RECORDS



Seeding
Control Section
El. 715.0'
Security Fence
PLAN - SPILLWAY
PROFILE - ℄ SPILLWAY
HOR.
VERT.
SPILLWAY PLAN & PROFILE
UNIT NO 1 THOMAS HILL PLANT
ASSOCIATED ELECTRIC COOPERATIVE
BURNS & McDONNELL ENGINEERING COMPANY
KANSAS CITY
R23

PLATE C-11



CONFORMING TO
CONSTRUCTION RECORDS

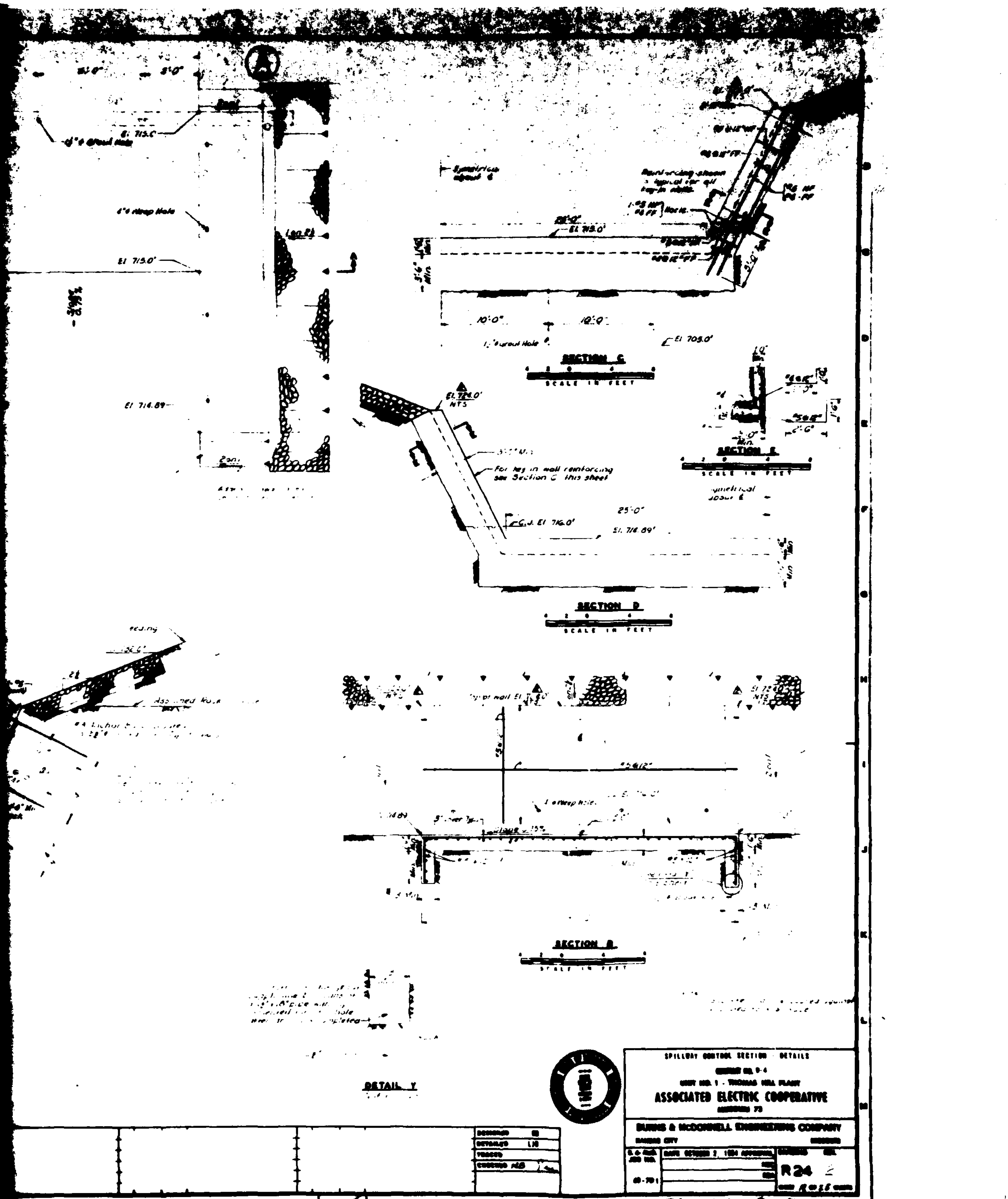
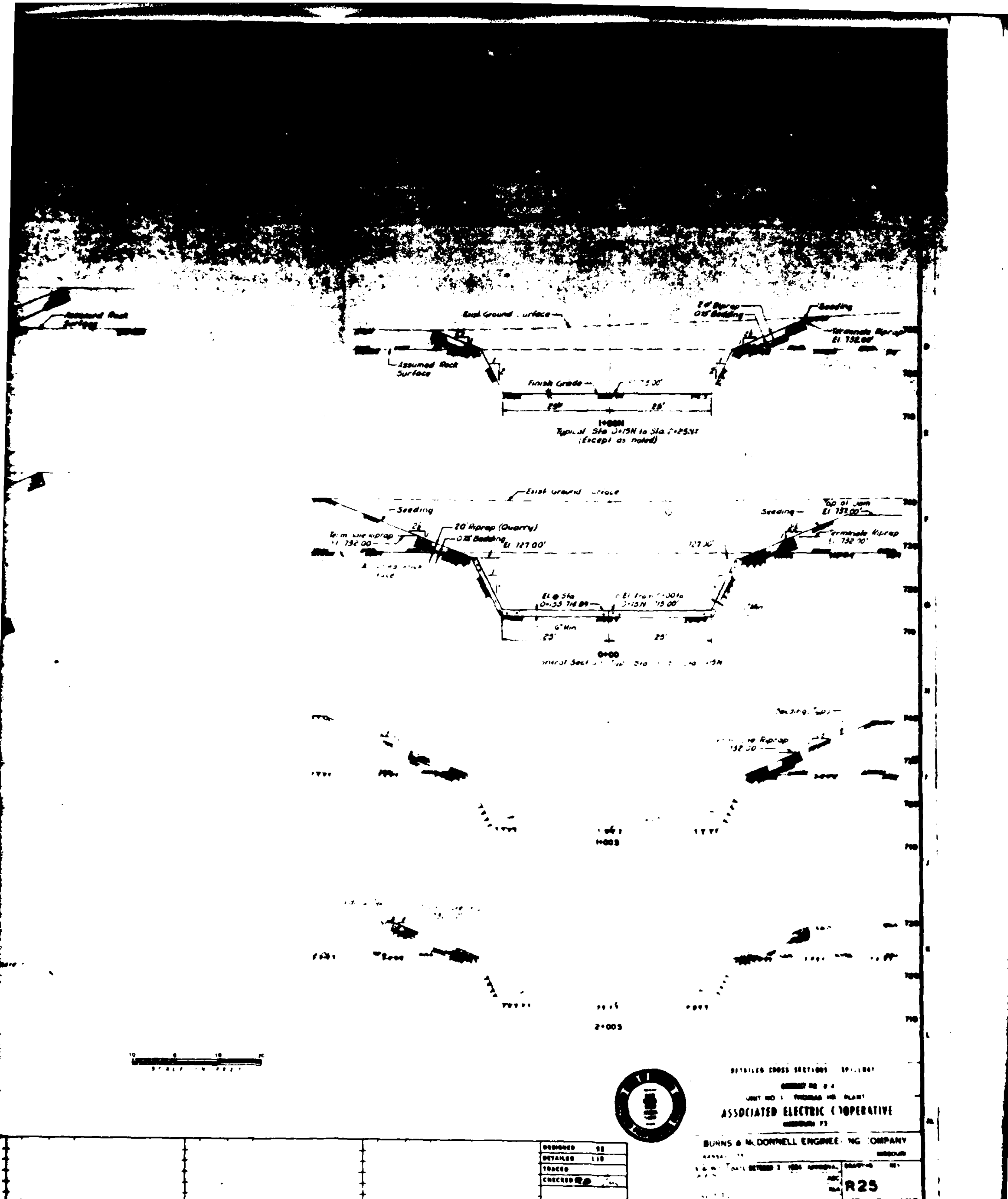

SECTION C
SCALE IN FEET
El 715.0'
El 705.0'
10'-0"
Reinforcing shown is typical for all key-in walls
4" Weep Hole
El 714.89'
SECTION E
SCALE IN FEET
For key in wall reinforcing see Section C this sheet
C.J. El 716.0'
25'-0"
El. 714.89'
SECTION D
SCALE IN FEET
Assumed Rock
SECTION B
SCALE IN FEET
DETAIL Y
SPILLWAY CONTROL SECTION - DETAILS
ASSOCIATED ELECTRIC COOPERATIVE
BURNS & McDONNELL ENGINEERING COMPANY
KANSAS CITY
MISSOURI
DESIGNED
DETAILED
TRACED
CHECKED
R24

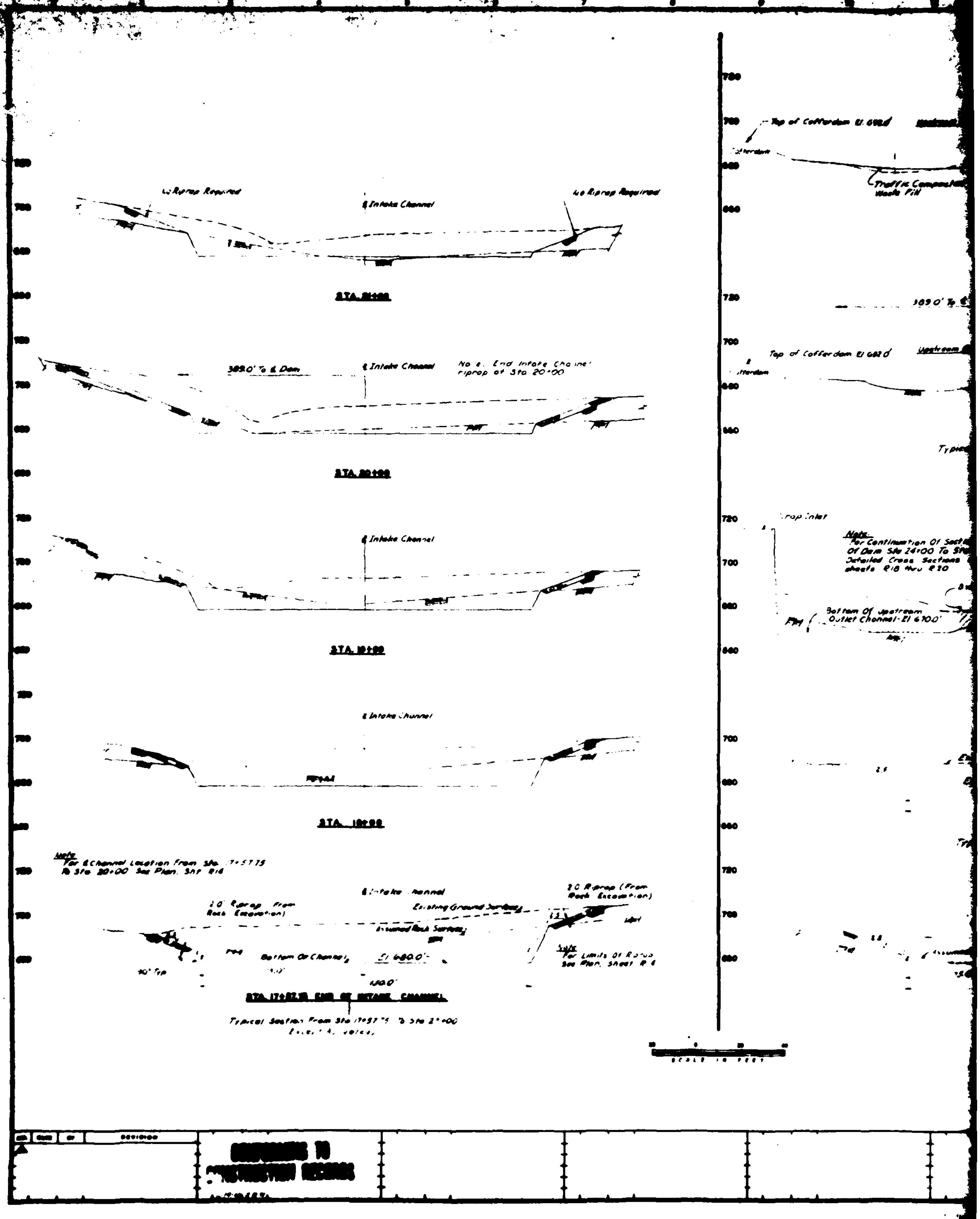
PLATE C-12

CONFORMING TO CONSTRUCTION RECORDS

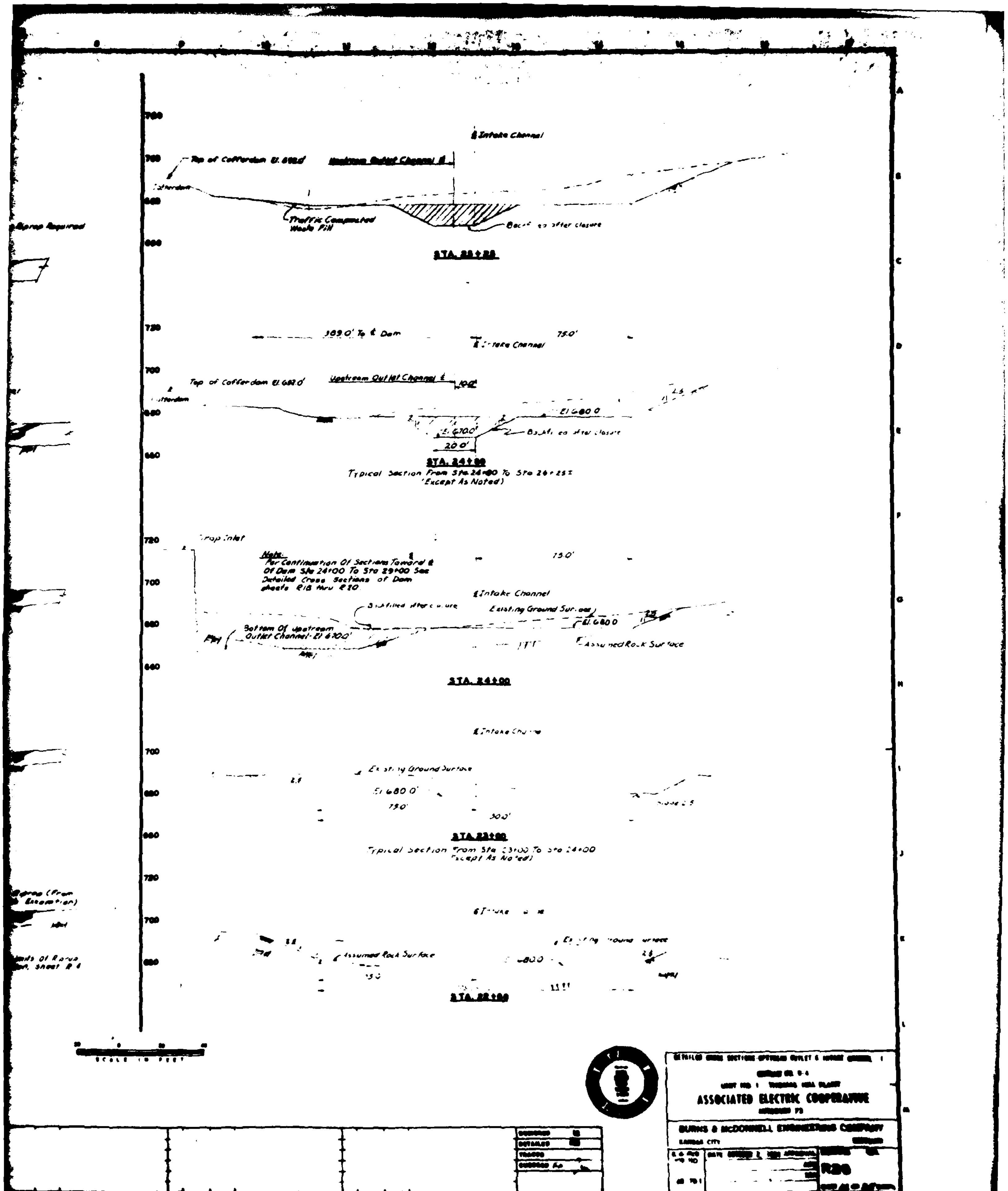


Assumed Rock Surface
Exist Ground Surface
Seeding
Terminate Riprap El 732.00'
Finish Grade
25'
1+00N
Typical Sta 0+15N to Sta 2+25N
(Except as noted)
Exist Ground Surface
Seeding
Top of Dam El 737.00'
Term. Riprap El 732.00'
2.0' Riprap (Quarry)
0.5' Bedding
El 727.00'
Terminate Riprap El 732.00'
6" Min
25'
0+00
1+00S
2+00S
SCALE IN FEET
DETAILED CROSS SECTIONS SPILLWAY
UNIT NO 1 THOMAS HILL PLANT
ASSOCIATED ELECTRIC COOPERATIVE
BURNS & McDONNELL ENGINEERING COMPANY
DESIGNED
DETAILED
TRACED
CHECKED
R25

PLATE C-13

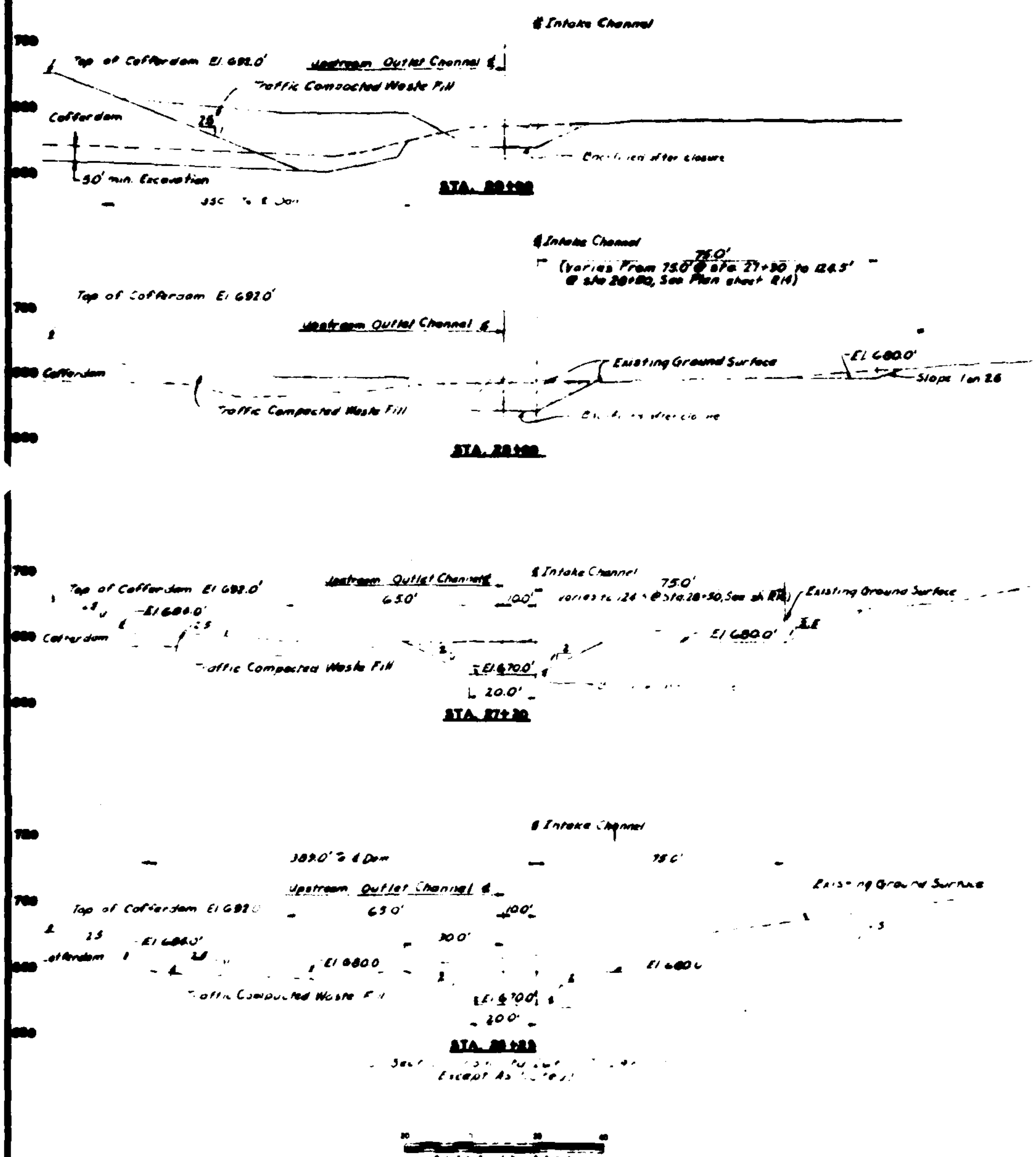


No Riprap Required
℄ Intake Channel
No Riprap Required
STA. 21+00
369.0' To ℄ Dam
℄ Intake Channel
No e. End Intake Channel riprap at Sta 20+00
STA. 20+00
℄ Intake Channel
STA. 19+00
℄ Intake Channel
STA. 18+00
Note
For ℄ Channel Location From Sta. 17+57.75 To Sta 20+00 See Plan. Sht R16
℄ Intake Channel
2.0' Riprap (From Rock Excavation)
Existing Ground Surface
Assumed Rock Surface
2.0' Riprap (From Rock Excavation)
Bottom Of Channel
El 680.0'
Note
For Limits Of Riprap See Plan, Sheet R16
140.0'
STA. 17+57.75 END OF INTAKE CHANNEL
Typical Section From Sta 17+57.75 To Sta 21+00
Except As Noted
Top of Cofferdam El 698.0'
Traffic Compacted Waste Fill
369.0' To ℄
Top of Cofferdam El 682.0'
Note
For Continuation Of Sections Of Dam Sta 24+00 To Sta ... Detailed Cross Sections ... sheets R18 thru R20
Bottom Of Upstream Outlet Channel - El 670.0'
SCALE IN FEET
CONFORMS TO CONSTRUCTION RECORDS
REVISIONS



Intake Channel
Top of Cofferdam El. 682.0'
Traffic Compacted Waste Fill
STA. 25+25
389.0' To ℄ Dam
75.0'
Top of Cofferdam El. 682.0'
Upstream Outlet Channel ℄
El. 680.0
El. 670.0'
20.0'
STA. 24+80
Typical Section From Sta. 24+80 To Sta. 26+25±
(Except As Noted)
Drop Inlet
Note:
For Continuation Of Sections Toward ℄ Of Dam Sta. 24+00 To Sta. 29+00 See Detailed Cross Sections of Dam sheets R18 thru R20
75.0'
℄ Intake Channel
Existing Ground Surface
El. 680.0
Bottom Of Upstream Outlet Channel - El. 670.0'
Assumed Rock Surface
STA. 24+00
Existing Ground Surface
El. 680.0'
75.0'
30.0'
STA. 23+00
Typical Section From Sta. 23+00 To Sta. 24+00
(Except As Noted)
Assumed Rock Surface
STA. 22+00
SCALE IN FEET
ASSOCIATED ELECTRIC COOPERATIVE
KANSAS CITY
R20

PLATE C-14



CONFORMING TO
CONSTRUCTION RECORDS

REVISION

UNIT NO. 1 THOMAS HILL PLANT

ASSOCIATED ELECTRIC COOPERATIVE

BURNS & McDONNELL ENGINEERING COMPANY

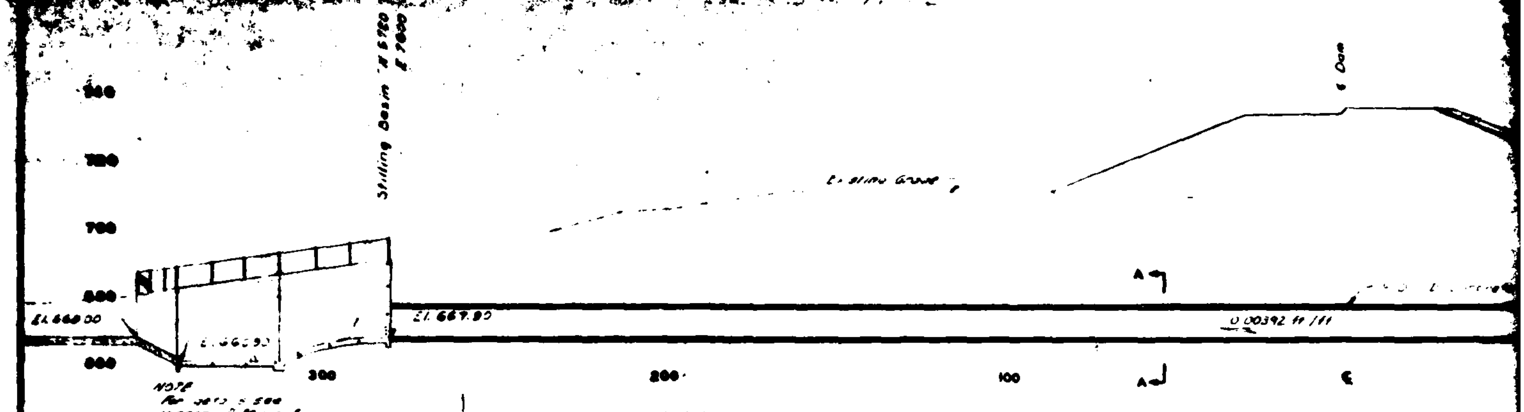
KANSAS CITY

DESIGNED	
DETAILED	
TRACED	
CHECKED	

B & McD JOB NO.

DATE

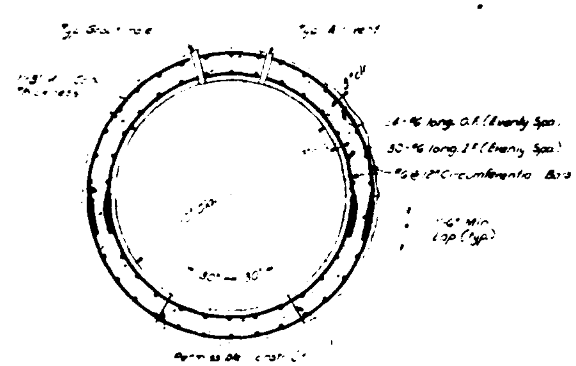
PLATE C-15



STATION 24+00 - LANDSIDE

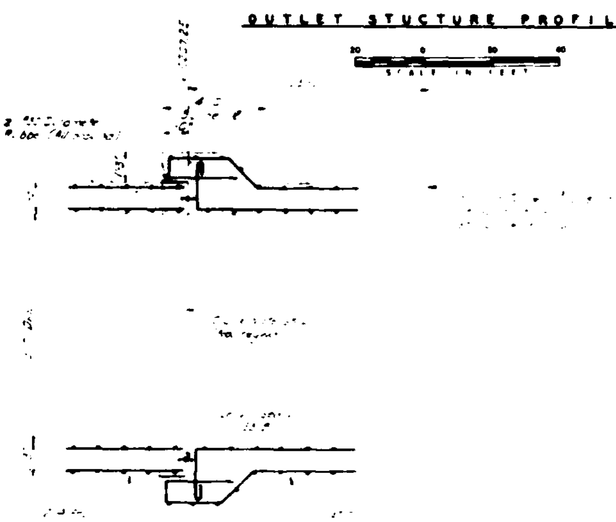
OUTLET STUCTURE PROFILE

SCALE IN FEET



SECTION A

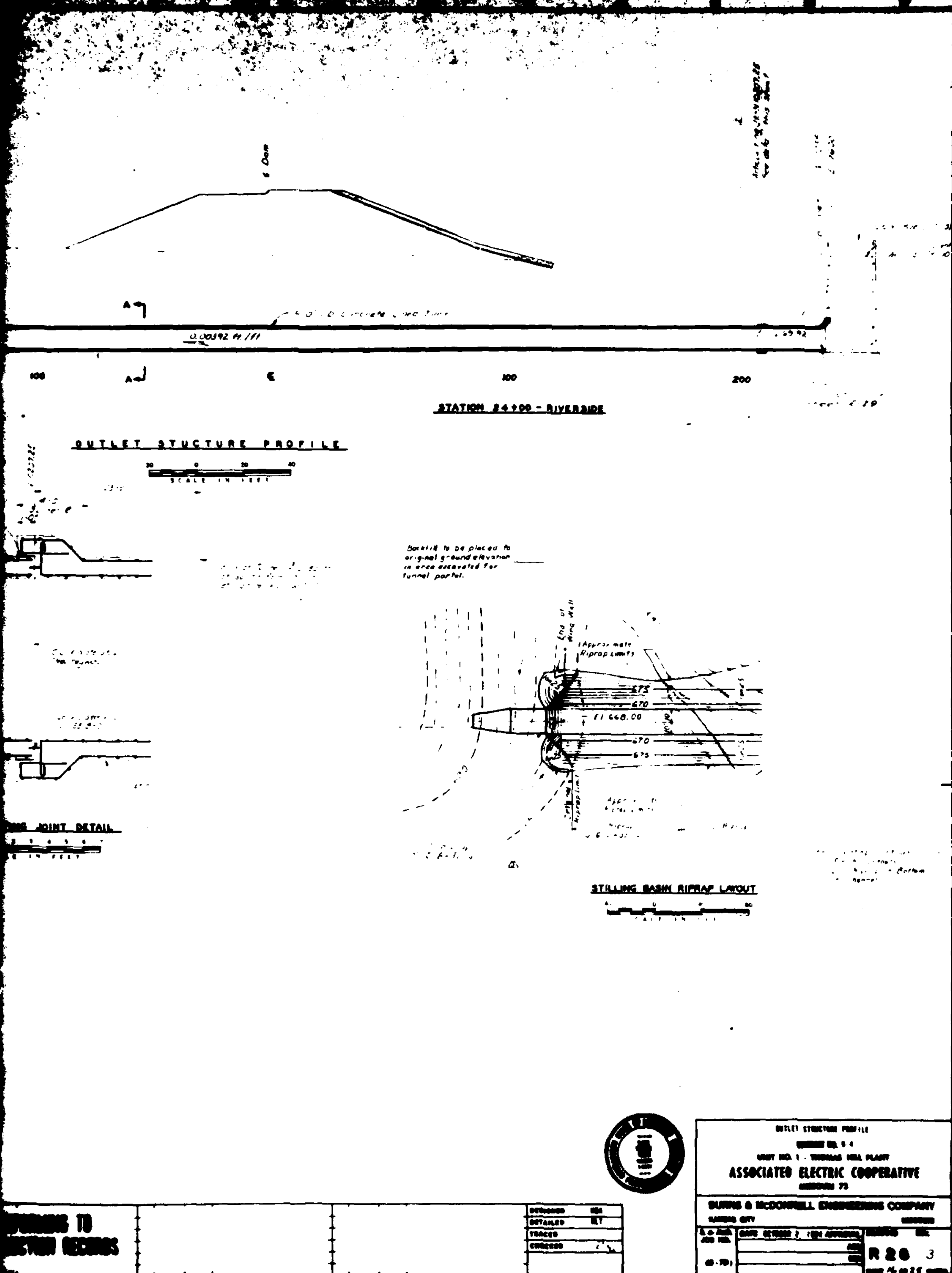
SCALE IN FEET



ARTICULATING JOINT DETAIL

SCALE IN FEET

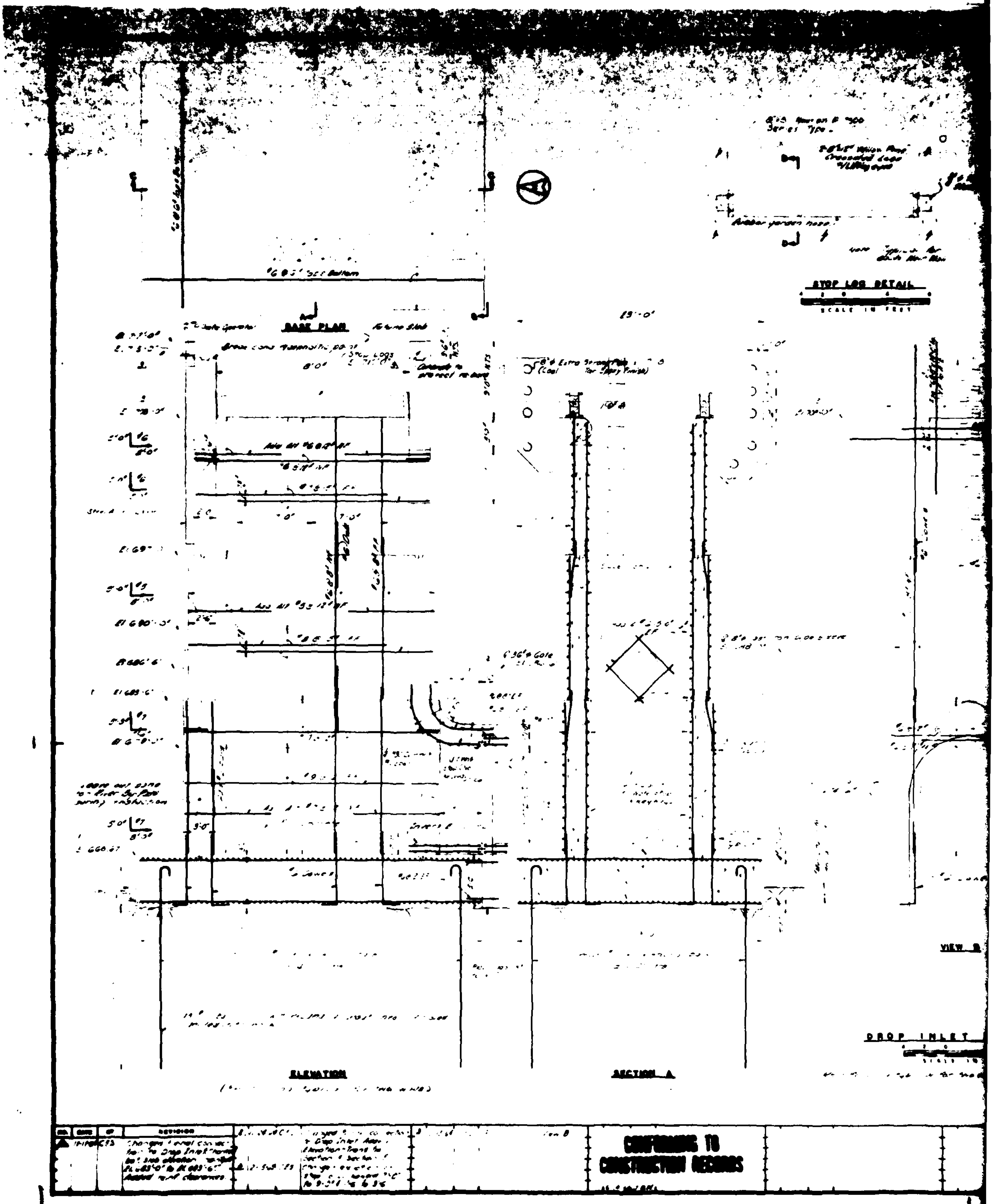
REVISION			
Changed ... thickness ... Added ... Inlet	Added ... Detail ...	Added Stilling Basin Riprap Layout with revised Riprap Limits shown.	CONFORMING TO CONSTRUCTION RECORDS



STATION 24+00 - RIVERSIDE
OUTLET STUCTURE PROFILE
0.00392 ft/ft
Backfill to be placed to original ground elevation in area excavated for tunnel portal.
Approximate Riprap Limits
El 668.00
STILLING BASIN RIPRAP LAYOUT
JOINT DETAIL
ASSOCIATED ELECTRIC COOPERATIVE
R 28

1 2

PLATE C-16



BASE PLAN
STOP LOG DETAIL
SCALE IN FEET
ELEVATION
SECTION A
VIEW B
DROP INLET
REVISION
CONFORMING TO
CONSTRUCTION RECORDS

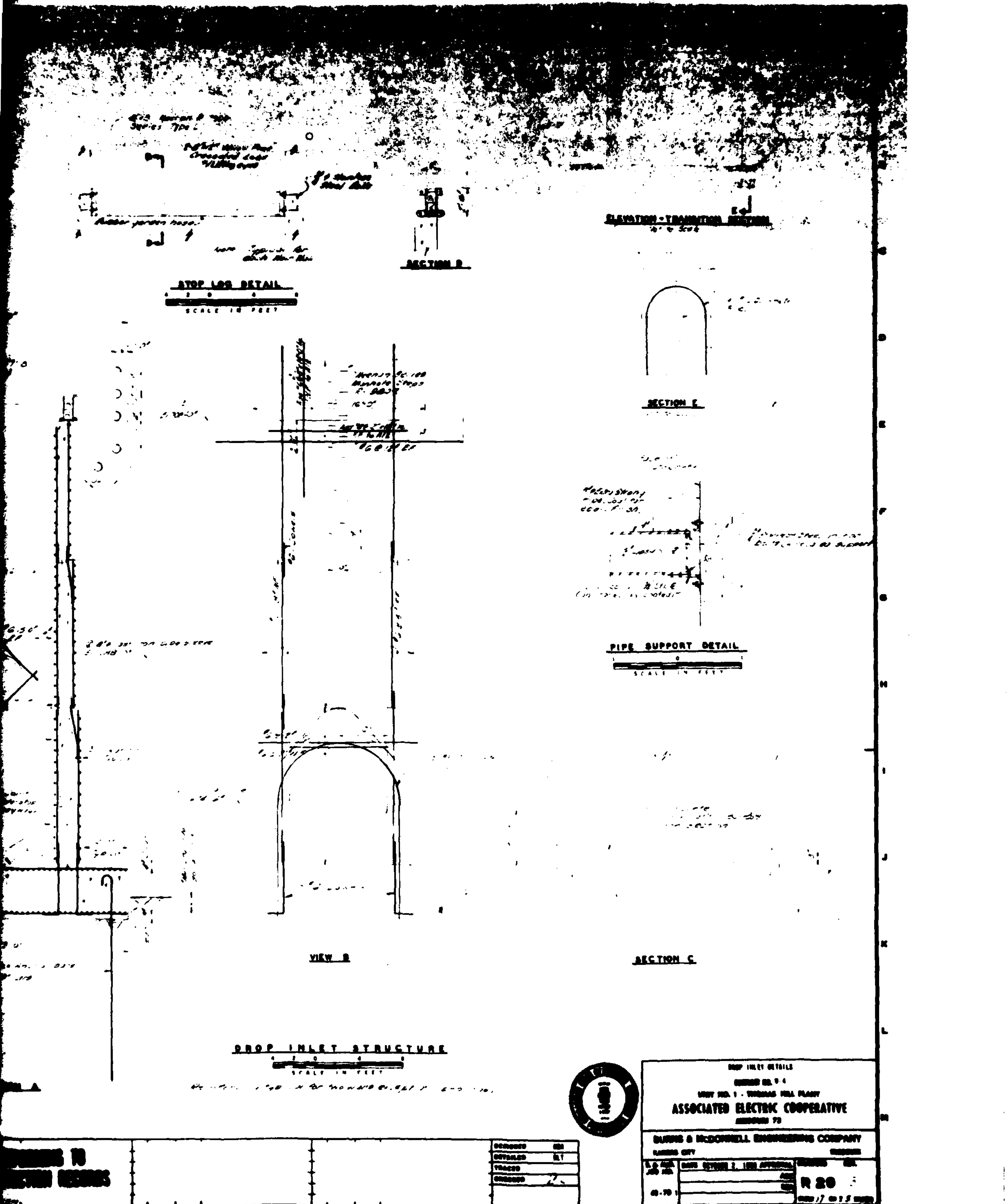
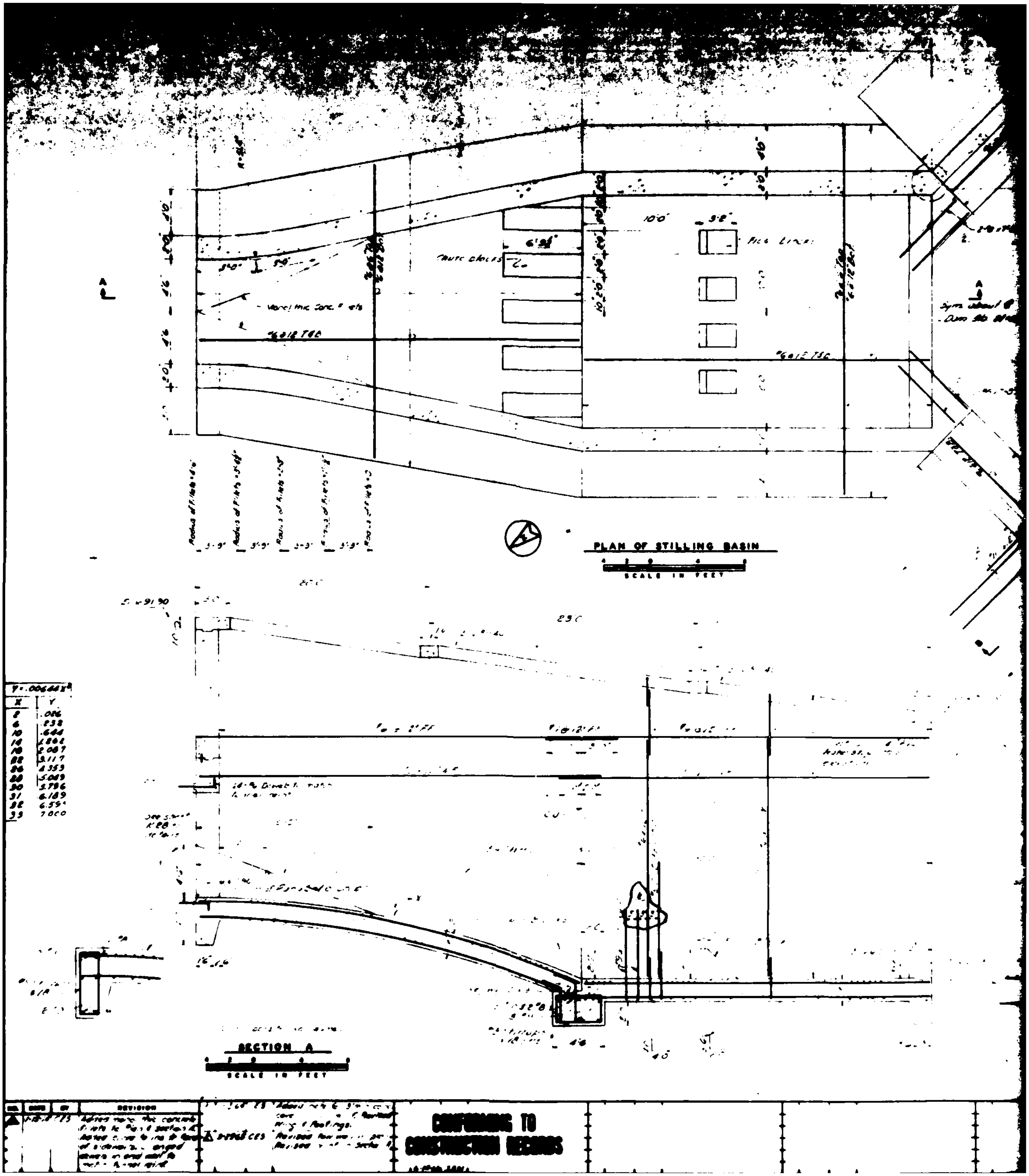
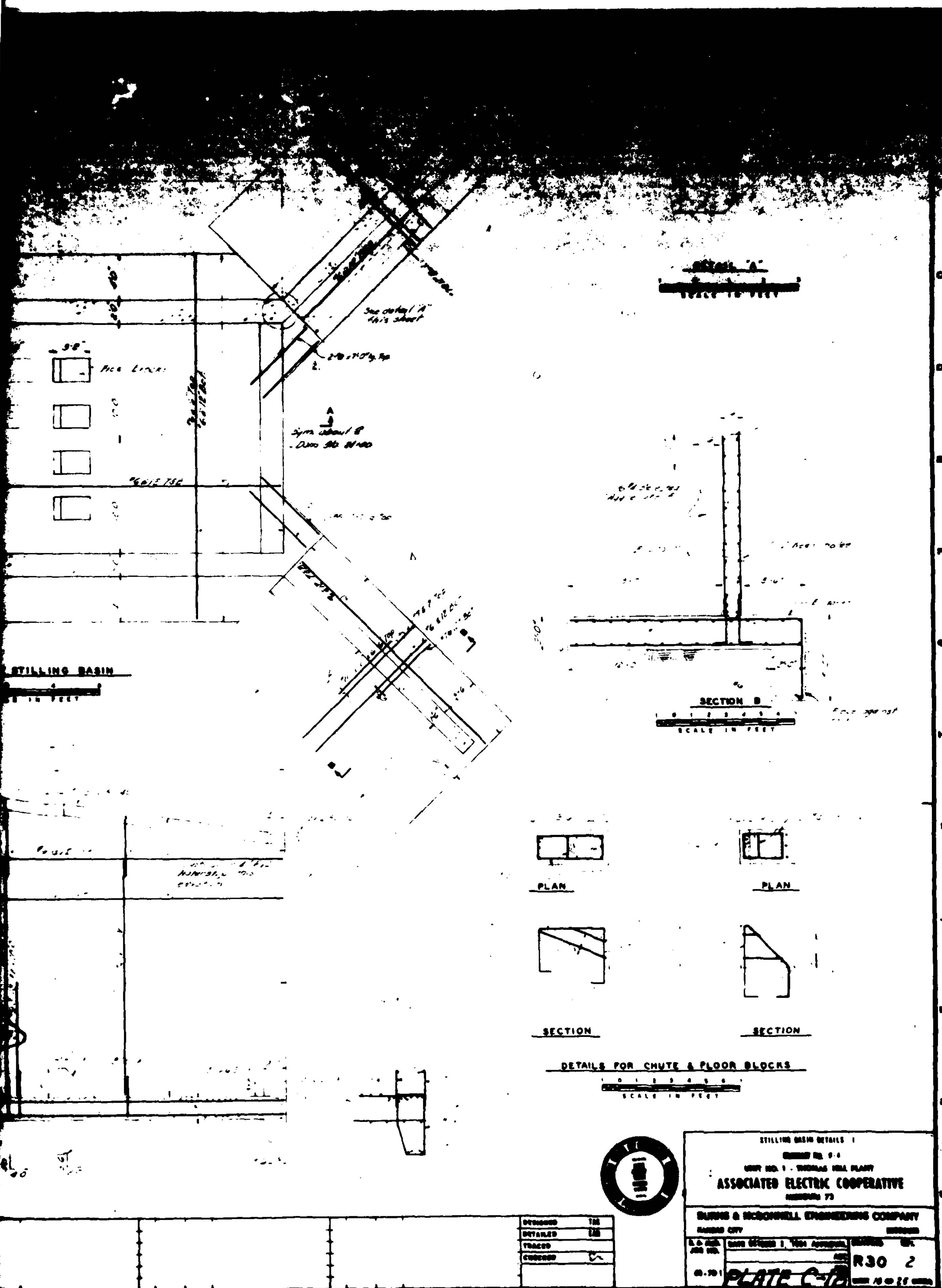
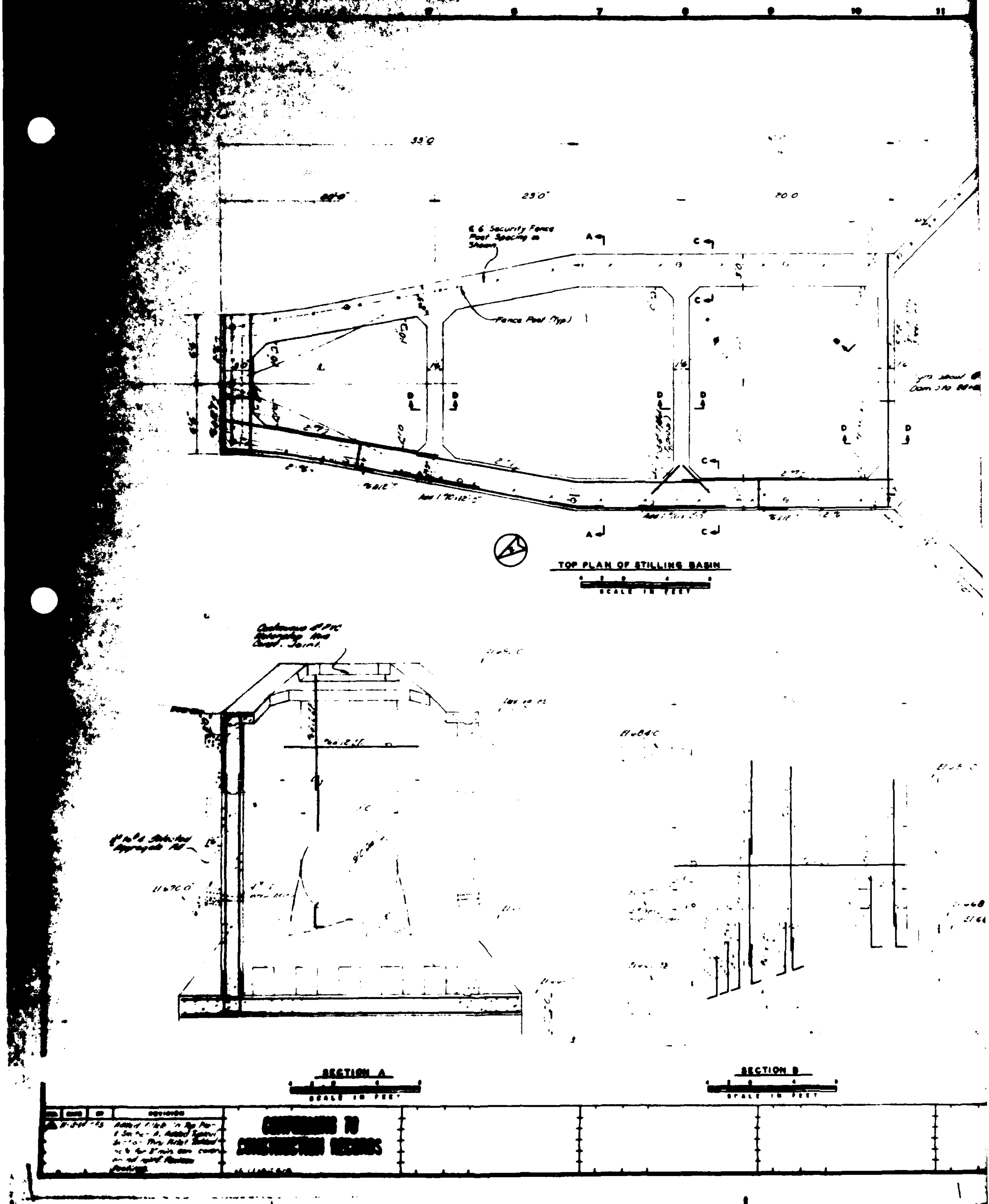

STOP LOG DETAIL
SCALE IN FEET
SECTION B
ELEVATION - TRANSITION SECTION
SECTION E
PIPE SUPPORT DETAIL
SCALE IN FEET
VIEW B
SECTION C
DROP INLET STRUCTURE
SCALE IN FEET
DROP INLET DETAILS
ASSOCIATED ELECTRIC COOPERATIVE
BURNS & McDONNELL ENGINEERING COMPANY
KANSAS CITY
R 20

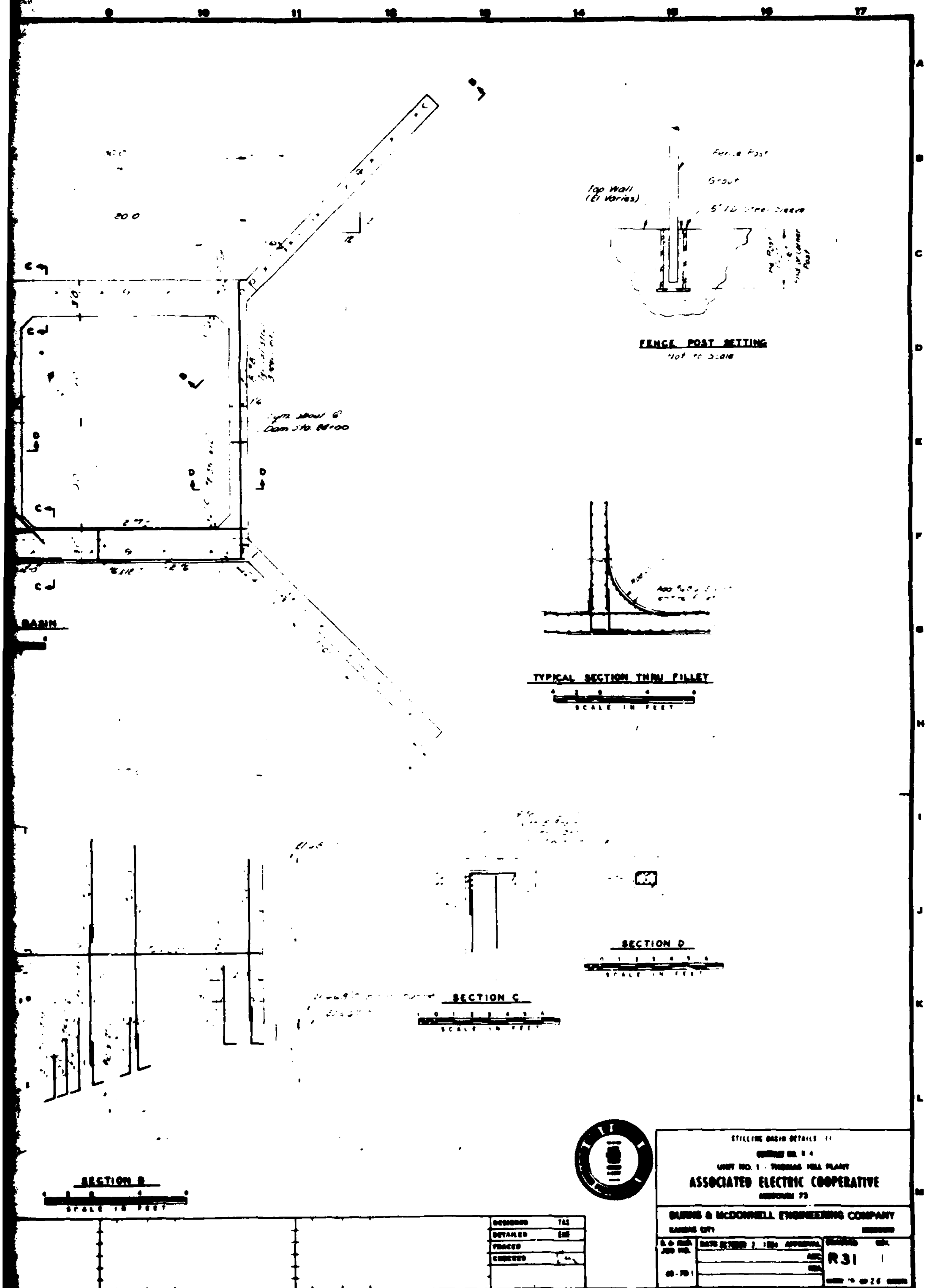
PLATE C-17



$Y = .00644X^2$	
X	Y
2	.026
6	.232
10	.644
14	1.262
18	2.087
22	3.117
26	4.353
28	5.049
30	5.796
31	6.189
32	6.59[illegible]
33	7.000


DETAIL "A"
SCALE IN FEET
See detail "A" this sheet
Pick Blocks
STILLING BASIN
SCALE IN FEET
SECTION B
SCALE IN FEET
PLAN
PLAN
SECTION
SECTION
DETAILS FOR CHUTE & FLOOR BLOCKS
SCALE IN FEET
STILLING BASIN DETAILS I
ASSOCIATED ELECTRIC COOPERATIVE
KANSAS CITY
R30 2
PLATE C-12


TOP PLAN OF STILLING BASIN
SCALE IN FEET
SECTION A
SCALE IN FEET
SECTION B
SCALE IN FEET
CONFORMING TO
CONSTRUCTION RECORDS



FENCE POST SETTING
Not to Scale
Fence Post
Grout
Top Wall
(El Varies)
TYPICAL SECTION THRU FILLET
SCALE IN FEET
SECTION D
SECTION C
SECTION B
ASSOCIATED ELECTRIC COOPERATIVE
UNIT NO. 1 - THOMAS HILL PLANT
BURNS & McDONNELL ENGINEERING COMPANY
KANSAS CITY
R31

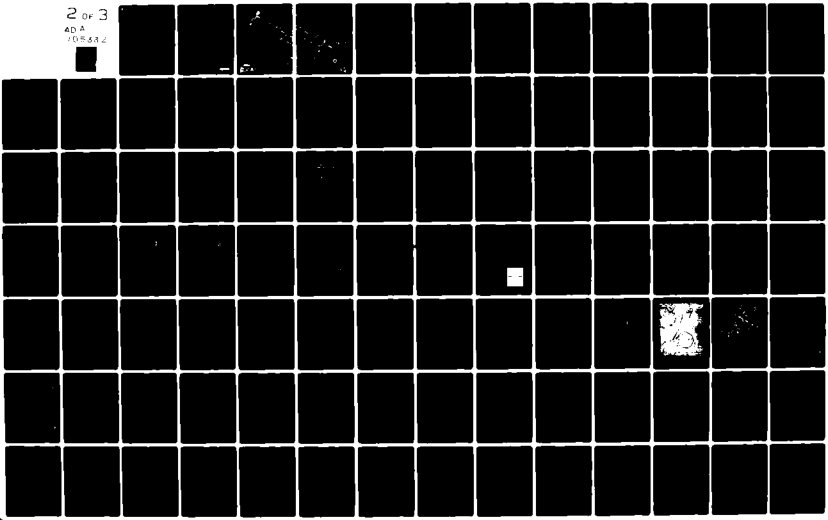
1 2

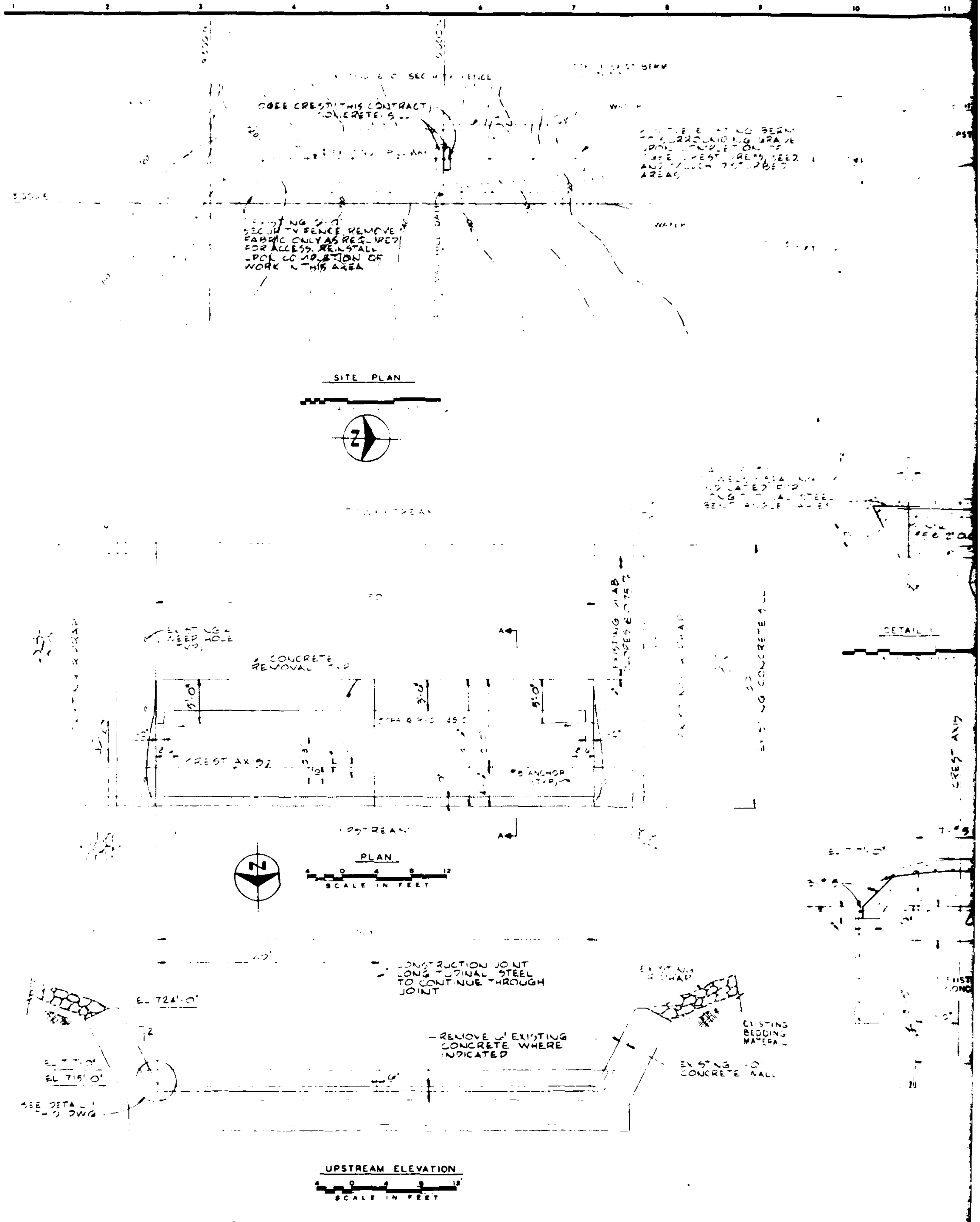
PLATE C-19

AD-A105 332 HOSKINS-WESTERN-SONDEREGGER INC LINCOLN NE F/G 13/13
NATIONAL DAM SAFETY PROGRAM. THOMAS HILL RESERVOIR DAM (MO 1013--ETC(U)
MAY 80 R S DECKER, G JAMISON, G ULMER DACW43-80-C-0071

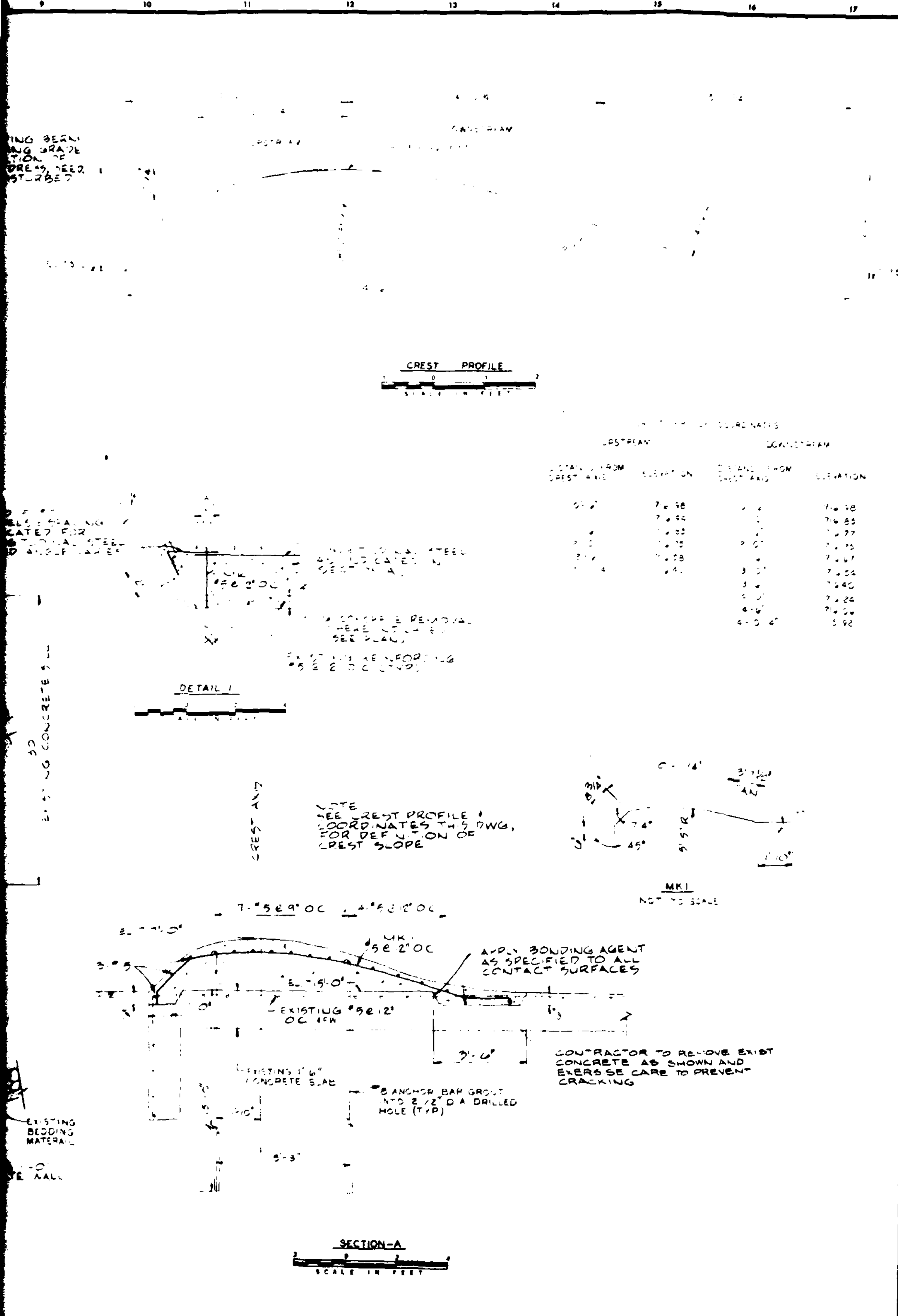
UNCLASSIFIED NL

2 OF 3
AD A
105332





OGEE CREST (THIS CONTRACT)
SITE PLAN
CONCRETE REMOVAL
CREST AXIS
UPSTREAM
PLAN
SCALE IN FEET
CONSTRUCTION JOINT LONGITUDINAL STEEL TO CONTINUE THROUGH JOINT
EL 724'-0"
REMOVE 6" EXISTING CONCRETE WHERE INDICATED
EL 715'-0"
EXISTING BEDDING MATERIAL
UPSTREAM ELEVATION
SCALE IN FEET
DETAIL



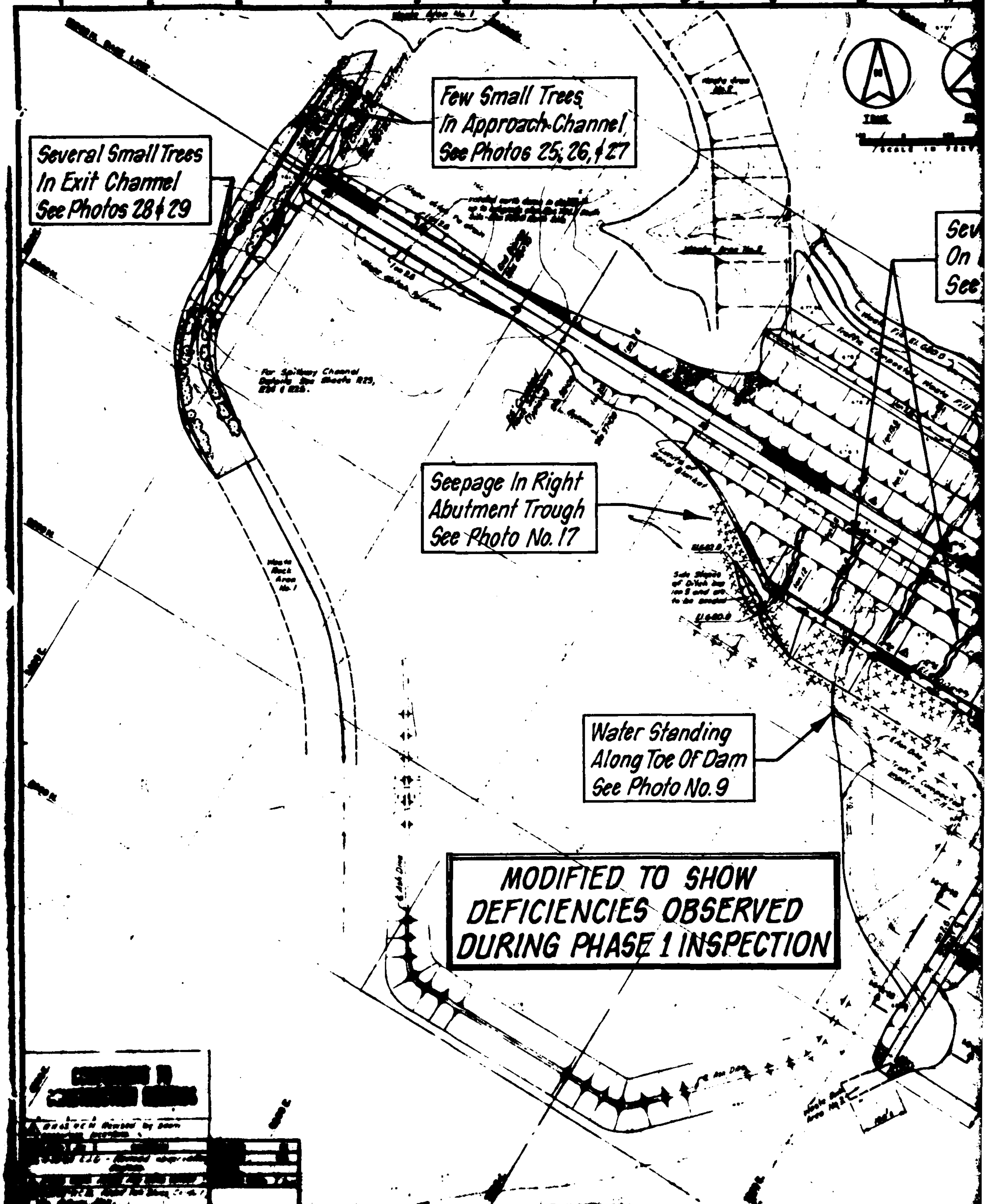
THOMAS HILL DAM
SPILLWAY MODIFICATION
CONTRACT NO. 311
SITE PREPARATION AND FOUNDATIONS

THOMAS HILL POWER PLANT
UNIT NO. 3
ASSOCIATED ELECTRIC COOPERATIVE
MISSOURI 73

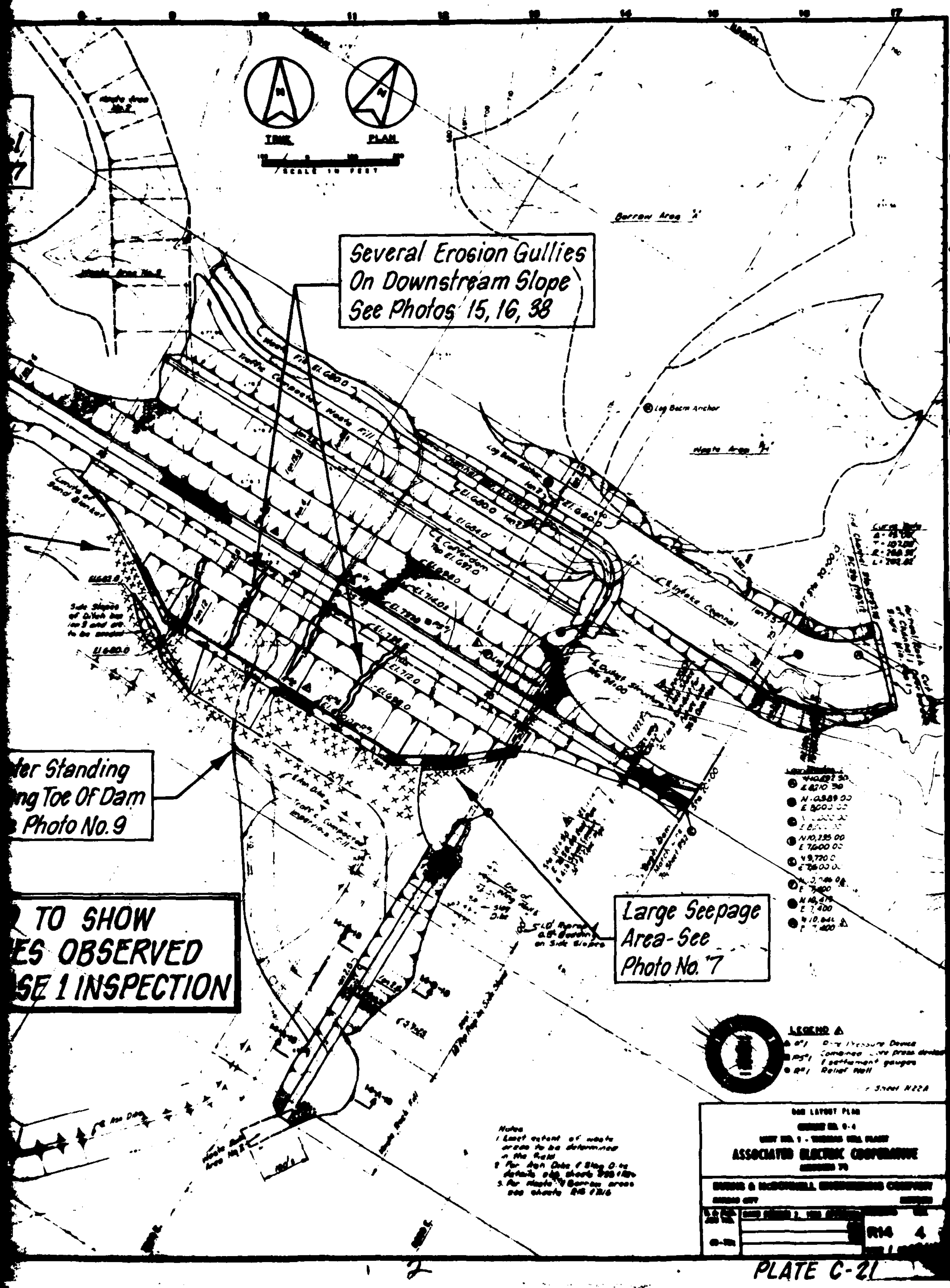
Burns & McDonnell

DATE MAR 27 1978
APP MAR 25 1978
DRAWING NO. Y 59 –
PROJECT 76-017-1

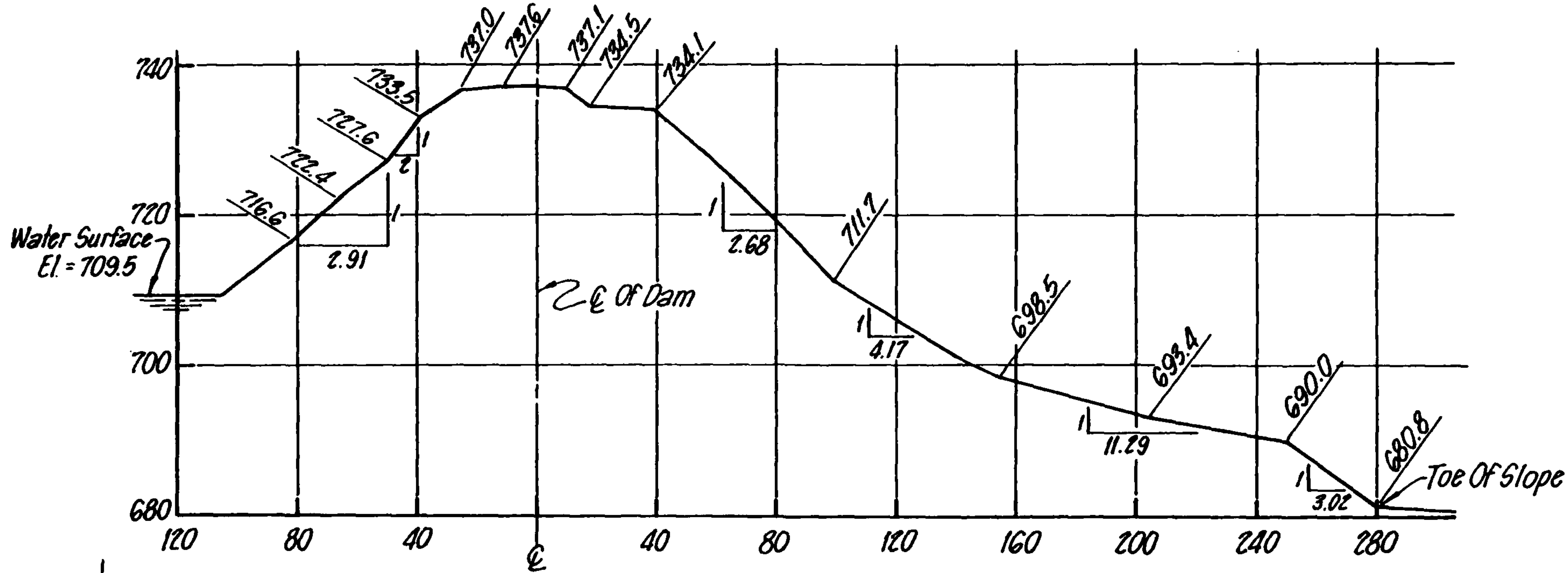
PLATE C-20



Few Small Trees
In Approach Channel
See Photos 25, 26, & 27
Several Small Trees
In Exit Channel
See Photos 28 & 29
Seepage In Right
Abutment Trough
See Photo No. 17
Water Standing
Along Toe Of Dam
See Photo No. 9
MODIFIED TO SHOW
DEFICIENCIES OBSERVED
DURING PHASE 1 INSPECTION

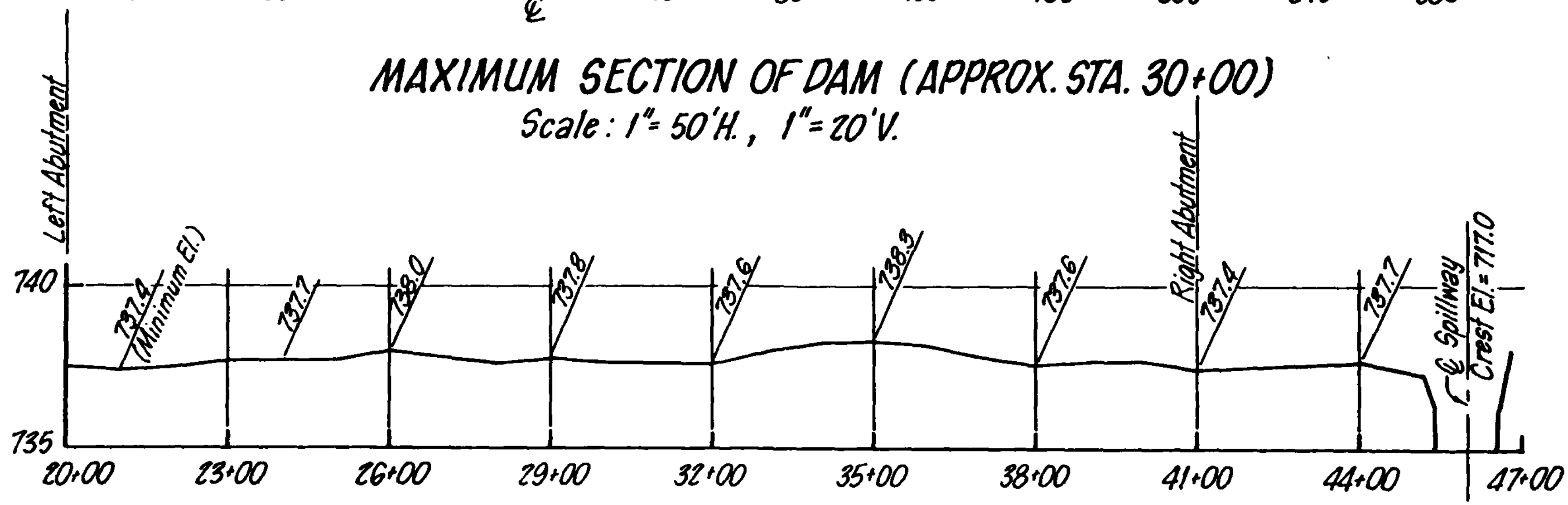


Several Erosion Gullies
On Downstream Slope
See Photos 15, 16, 38
Borrow Area "A"
Log Beam Anchor
Large Seepage
Area- See
Photo No. 7
der Standing
ng Toe Of Dam
Photo No. 9
TO SHOW
ES OBSERVED
SE 1 INSPECTION
LEGEND
ASSOCIATED ELECTRIC COOPERATIVE
PLATE C-21



MAXIMUM SECTION OF DAM (APPROX. STA. 30+00)

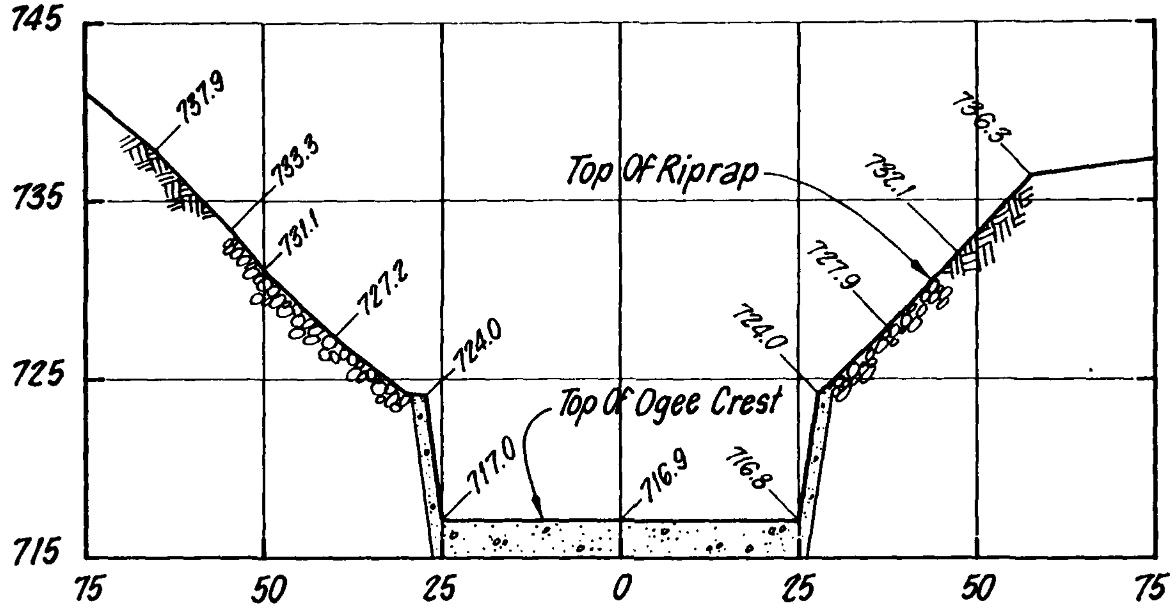
Scale: 1" = 50' H., 1" = 20' V.



PROFILE ALONG CENTERLINE OF DAM

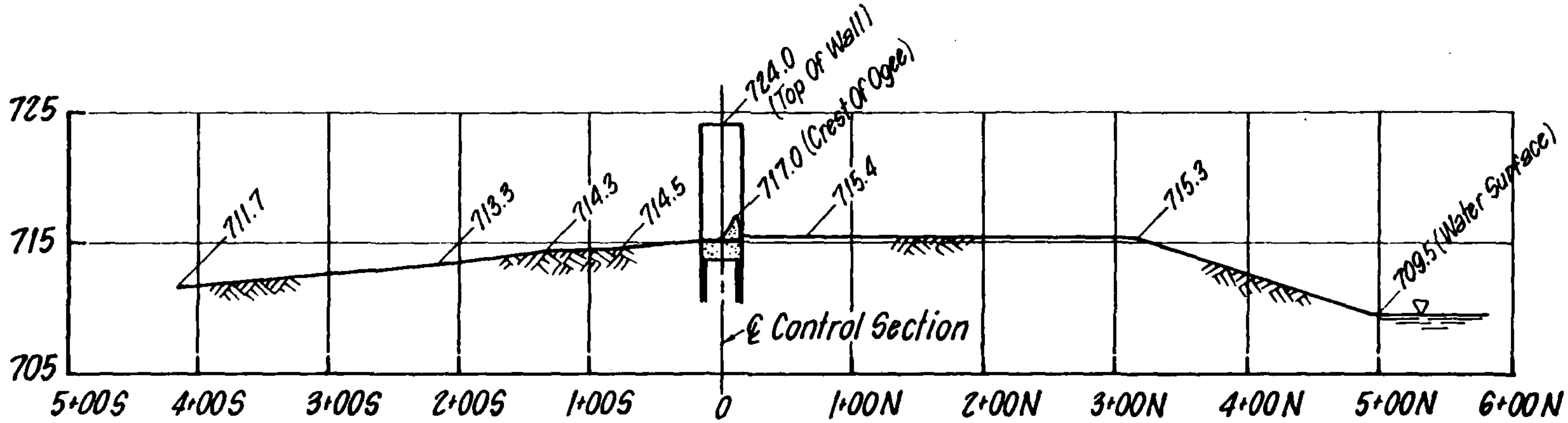
Scale: 1" = 300' H., 1" = 5' V.

PLATE C-22



SECTION OF SPILLWAY AT THE CONTROL SECTION

Scale: 1" = 25' H.
1" = 10' V.



CENTERLINE PROFILE OF EMERGENCY SPILLWAY

5' 0 5' 10'
Graphic Scale: 1" = 10' Vert.

50' 0 50' 100'
Graphic Scale: 1" = 100' Horiz.

APPENDIX D
HYDRAULIC AND HYDROLOGIC DATA

HYDROLOGIC COMPUTATIONS

1. The SCS dimensionless unit hydrograph and the systemized computer program HEC-1 (Dam Safety Version), July 1978, prepared by the Hydrologic Engineering Center, U.S. Corps of Engineers, Davis, California, were used to develop the inflow hydrographs (See this Section).

   a. Forty-eight hour, 1 percent probability rainfall for the dam location was taken from the data for the rainfall station at Moberly, Missouri as supplied by the St. Louis District, Corps of Engineers during a Hydraulic/Hydrologic Training Conference on 30 April, 1980. The forty-eight hour probable maximum precipitation was taken from the curves of Hydrometeorological Report No. 33 and current Corps of Engineers and St. Louis policy and guidance for hydraulics and hydrology.

   b. Drainage area = 147 square miles (94,080 acres).

   c. Time of concentration of runoff = 35 hours. The time of concentration was computed assuming the relationship lag = 0.6 x (Time of Concentration) with lag = 21 hours (from "Hydrologic Report" by Burns and McDonnell). The time of concentration was verified by breaking the watercourse length into 9 segments and computing time of concentration by the "Kirpich" method. This resulted in a time of concentration of 32 hours.

   d. The antecedent storm conditions for the probable maximum precipitation were heavy rainfall and low temperatures which occurred on the previous 5 days (SCS AMC III). The antecedent storm conditions for the 1 percent probability precipitation were an average of the conditions which have preceded the occurrence of the maximum annual flood on numerous watersheds (SCS AMC II). The initial pool elevation was assumed at the crest of the riser. No antecedent storm was required due to the utilization of the forty-eight hour storm.

   e. The total forty-eight hour storm duration losses for the 1 percent probability storm were 2.14 inches. The total losses for the PMF storm were 1.02 inches. These data are based on SCS runoff curve No. 82 and No. 92 for antecedent moisture conditions SCS AMC II and AMC III respectively. The watershed is composed of primarily SCS hydrologic soil groups B, C and D. Wabash silty clay (D) and Blackoar silt loam (C) soil groups are located on the floodplain and lower slopes and consist of approximately 19 percent of the watershed. Land use is primarily cultivated crops (straight row). Lindley loam (C) and Goss cherty silt loam (B) are located on the hillsides and consist of approximately 40% of the watershed with land use in pasture (approximately 90 percent) and timber (approximately 10 percent). The uplands and ridges consist of Armstrong loam (D) and Leonard silt loam (D) with land use being primarily small grain (straight row).

f. Average soil loss rates = 0.02 inches per hour approximately. (for PMF storm, AMC III).

2. The combined discharge rating consisted of three components: the flow through the principal or service spillway, the flow through the emergency spillway and the flow going over the top of the dam.

a. The principal spillway was developed by using the weir, orifice, and full conduit flow equations:

(1) Weir flow equation ($Qw = CLH^{1.5}$)
where C = weir coefficient = 3.1 (SCS Engr. Memo 50)
L = length of weir, ft. = 36
H = total head, ft. (Pool elevation - 709.0)

(2) Orifice equation for 8-inch diameter pipe sleeve ($Qo = CA\sqrt{2gH}$)
where C = orifice equation = 0.6
A = area of opening, ft.^{2} = 0.35
H = total head, ft. (Pool elevation - 688.0)

(3) Full conduit flow equation ($Q = a\sqrt{\frac{2gh}{1+Ke+Kb+KpL}}$)
where a = area of conduit, ft.^{2} = 63.62
L = length of conduit, ft. = 515
Kp = coefficient for conduit friction loss = $\frac{5100n^2}{D^{1.33}}$=0.002231
where n=0.015 and D is the diameter in inches (From V.T. Chow's Handbook of Applied Hydrology, page 21-64)
Ke = coefficient for entrance loss = 0.50
(from V.T. Chow's Handbook of Applied Hydrology, page 21-64)
Kb = coefficient for bend loss = 0.45
(from V.T. Chow's Handbook of Applied Hydrology, page 21-64)
h = total head, ft. (Pool elevation - 673.3)

(4) In determining the principal rating curve, the 36-inch diameter sluice gate was assumed to be closed due to the fact that an operator may not be on hand at the time of storm.

(5) Weir flow over the riser and orifice flow thru the 8-inch diameter pipe sleeve control until pool elevation rises above 715+ at which time the conduit controls the discharge.

b. The emergency spillway ratings were developed using the method outlined in example 1, procedure 1, page 379 of Design of Small Dams by the Bureau of Reclamation for uncontrolled overflow ogee crests.

(1) The method uses the basic weir flow equation: $Q - CLH^{1.5}$

where C = weir coefficient derived from a design head (Ho) of 17 feet and adjusted for the depth of approach, relation of actual crest shape to ideal mappe shape, upstream face slope, downstrea apron interference, and downstream submergence.
(C varied from 2.90 to 3.15)

L = weir length, ft. = 50
H = total head, ft.

(2) The approach channel losses were included in the computations assuming friction loss through the channel (Mannings "n" = 0.035) and assuming an entrance loss = 0.1 (approach velocity head).

c. The flows over the dam were developed using the dam overtopping analysis (Flow over non-level dam crest) within the HEC-1 (Dam Safety Version) program.

3. Floods were routed through the reservoir using the HEC-1 (Dam Safety Version) program to determine the capabilities of the spillway and dam embankment crest. The input, output, and plotted hydrographs are attached in this section.

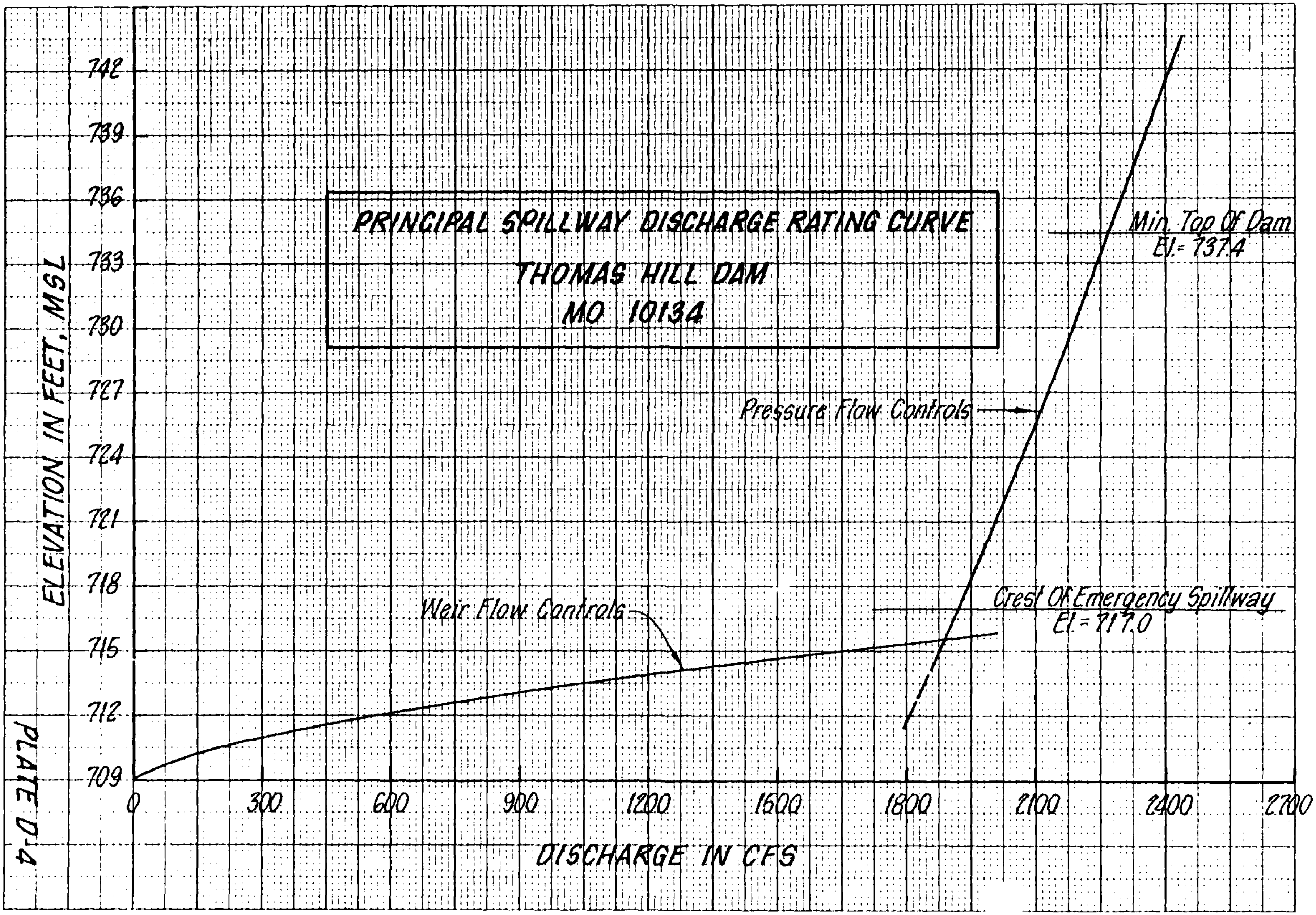

PRINCIPAL SPILLWAY DISCHARGE RATING CURVE
THOMAS HILL DAM
MO 10134
Min. Top Of Dam
El. = 737.4
Pressure Flow Controls
Crest Of Emergency Spillway
El. = 717.0
Weir Flow Controls
ELEVATION IN FEET, MSL
742
739
736
733
730
727
724
721
718
715
712
709
0
300
600
900
1200
1500
1800
2100
2400
2700
DISCHARGE IN CFS

PLATE D-4

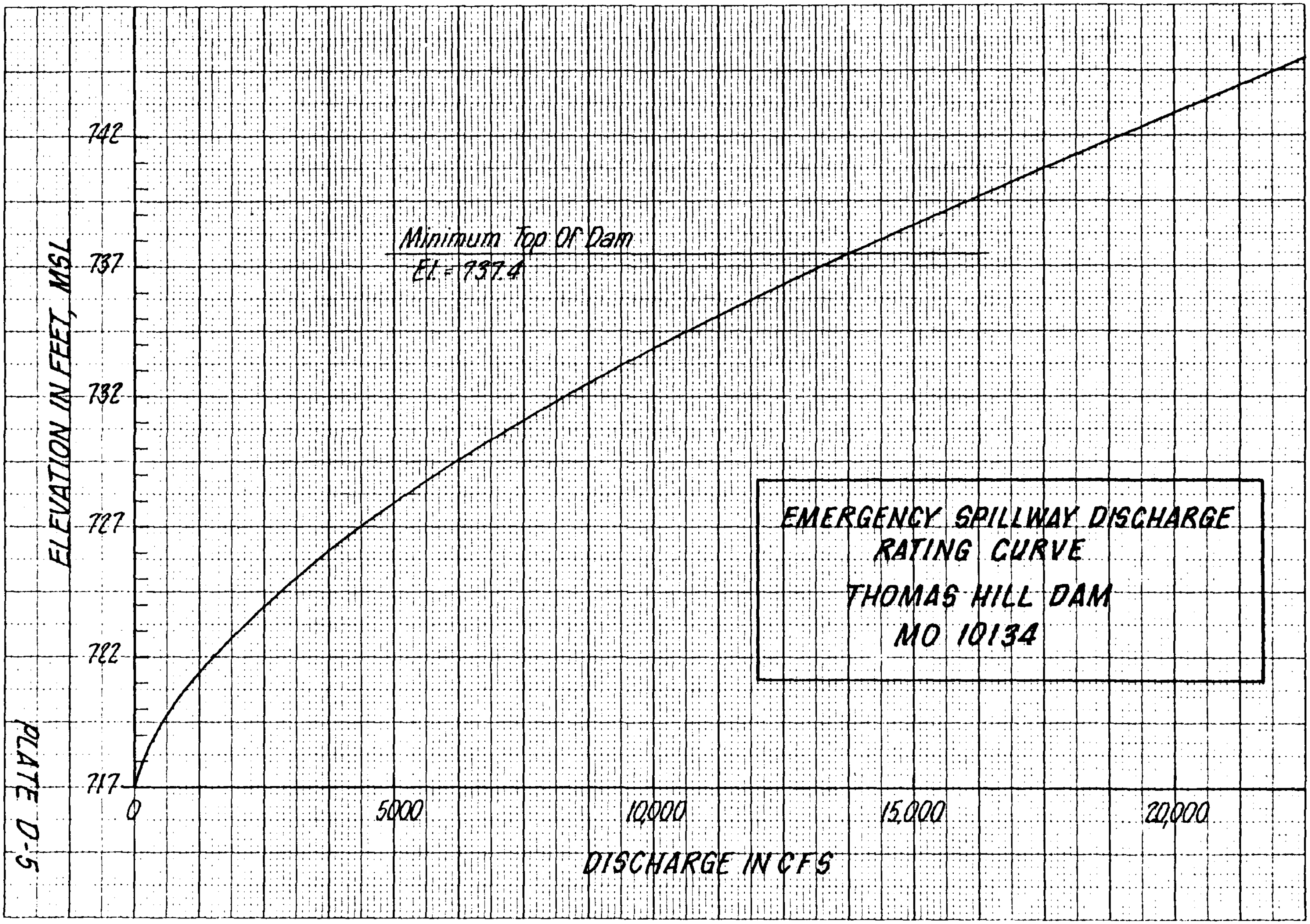

EMERGENCY SPILLWAY DISCHARGE
RATING CURVE
THOMAS HILL DAM
MO 10134
Minimum Top Of Dam
El. = 737.4
ELEVATION IN FEET, MSL
742
737
732
727
722
717
0
5000
10,000
15,000
20,000
DISCHARGE IN CFS

PLATE D-5

LISTING OF CARD INPUT DATA

```
A1       ANALYSIS OF DAM OVERTOPPING USING RATIOS OF PMF
A2       H&H ANALYSIS OF SAFETY OF THOMAS HILL DAM - MO 10134
A3       RATIOS OF PMF ROUTED THROUGH THE RESERVOIR
B 000200000000100000000                                   00000000000000000000003
B1000005
J 000001000000200000001
J10000.5000001.0
K 0000000000001                    000000000000000000001
K1       CALCULATION OF INFLOW HYDROGRAPH TO RESERVOIR 10134
M 0000010000000200000147.          0000147.000001.0                  00000001
P 000000000024.50000007600000094000001040000115
T                                                          -1.0    -92.0
W2       0000021.
X 000000    -.0100000001
K 00000100000002                   000000020000000000000001
K1       ROUTED FLOWS THROUGH RESERVOIR  10134
Y                          000000100000001
Y1000001                                                   -709       -1
Y400070900000710000007120000071300000714000007160000071700000718000007200000[illegible]
Y4000724000007260000072800000730000007320000073400000736000007370000073800000740
Y5000008000001200000058800000901000012560000187500001917000020890000263200003524
Y5004565000057300000714500008684000104720001235900014396000154400001658300018910
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K 000099
A
A
A
A
A
```

```
*************************************
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION        JULY 1978
  LAST MODIFICATION [illegible] FEB 7[illegible]
*************************************

RUN DATE [illegible]
     TIME [illegible]


          ANALYSIS OF DAM OVERTOPPING USING RATIOS OF PMF
          HMH ANALYSIS OF SAFETY OF THOMAS HILL DAM - MO 10134
          RATIOS OF PMF ROUTED THROUGH THE RESERVOIR

                         JOB SPECIFICATION
   NQ      NHR     NMIN     IDAY      IHR     IMIN    METRC     IPLT     IPRT    NSTAN
  200        1        0        0        0        0        0        0        3        0
                           JOPER      NWT    LROPT    TRACE
                               5        0        0        0

               MULTI-PLAN ANALYSES TO BE PERFORMED
                  NPLAN= 1 NRTIO= 2 LRTIO= 1
  RTIOS=     .50    1.00


**********          **********          **********          **********          **********

                     SUB-AREA RUNOFF COMPUTATION

       CALCULATION OF INFLOW HYDROGRAPH TO RESERVOIR 10134

             ISTAQ   ICOMP   IECON   ITAPE    JPLT    JPRT   INAME  ISTAGE   IAUTO
            000001       0       0       0       0       0       1       0       0

                            HYDROGRAPH DATA
   IHYDG    IUHG   TAREA    SNAP   TRSDA   TRSPC   RATIO   ISNOW   ISAME   LOCAL
       1       2  147.00    0.00  147.00    1.00   0.000       0       1       0

                             PRECIP DATA
              SPFE     PMS      R6     R12     R24     R48     R72     R96
              0.00   24.50   76.00   94.00  104.00  115.00    0.00    0.00

                              LOSS DATA
 LROPT   STRKR   DLTKR   RTIOL   ERAIN   STRKS   RTIOK   STRTL   CNSTL   ALSMX   RTIMP
     0    0.00    0.00    1.00    0.00    0.00    1.00   -1.00  -92.00    0.00    0.00

   CURVE NO =  -92.00   WETNESS =   -1.00   EFFECT CN =   92.00

                         UNIT HYDROGRAPH DATA
                      TC=  0.00     LAG= 21.00

                            RECESSION DATA
                 STRTQ=     0.00    ORCSN=    -.01    RTIOR= 1.00

   UNIT HYDROGRAPH107 END OF PERIOD ORDINATES, TC=     0.00 HOURS, LAG=  21.00  VOL= 1.00
     47.        92.       190.       298.       427.       565.       728.       913.      1122.      1347.
 [illegible]   1914.      2203.      2449.      2694.      2867.      3036.      3143.      3236.      3278.
 [illegible] [illegible]  3278.      3236.      3143.      3048.      2941.      2833.      2710.      2587.
 [illegible] [illegible]  2106.  [illegible]    1756.      1603.      1470.      1363.      1260.      1148.
```

PLATE D-7

[illegible]	1001.	924.	868.	813.	756.	700.	651.	605.	559.
513.	473.	442.	412.	381.	351.	328.	305.	282.	259.
[illegible]	224.	207.	190.	176.	164.	153.	141.	130.	122.
113.	105.	97.	90.	84.	78.	72.	67.	62.	57.
53.	49.	46.	42.	39.	36.	34.	33.	31.	29.
27.	25.	23.	22.	20.	18.	16.	15.	13.	12.
10.	8.	7.	5.	4.	2.	1.			

END-OF-PERIOD FLOW

MO.DA	HR.MN	PERIOD	RAIN	EXCS	LOSS	COMP Q	MO.DA	HR.MN	PERIOD	RAIN	EXCS	LOSS	COMP Q
1.01	1.00	1	.02	0.00	.02	0.	1.05	5.00	101	0.00	0.00	0.00	5308.
1.01	2.00	2	.02	0.00	.02	0.	1.05	6.00	102	0.00	0.00	0.00	4717.
1.01	3.00	3	.02	0.00	.02	0.	1.05	7.00	103	0.00	0.00	0.00	4549.
1.01	4.00	4	.02	0.00	.02	0.	1.05	8.00	104	0.00	0.00	0.00	4215.
1.01	5.00	5	.02	0.00	.02	0.	1.05	9.00	105	0.00	0.00	0.00	3713.
1.01	6.00	6	.02	0.00	.02	0.	1.05	10.00	106	0.00	0.00	0.00	3432.
1.01	7.00	7	.08	.00	.08	0.	1.05	11.00	107	0.00	0.00	0.00	[illegible]
1.01	8.00	8	.08	.01	.07	0.	1.05	12.00	108	0.00	0.00	0.00	3123.
1.01	9.00	9	.08	.02	.06	2.	1.05	13.00	109	0.00	0.00	0.00	2900.
1.01	10.00	10	.08	.03	.05	4.	1.05	14.00	110	0.00	0.00	0.00	2692.
1.01	11.00	11	.08	.03	.04	10.	1.05	15.00	111	0.00	0.00	0.00	2496.
1.01	12.00	12	.08	.04	.04	19.	1.05	16.00	112	0.00	0.00	0.00	2311.
1.01	13.00	13	.20	.12	.08	35.	1.05	17.00	113	0.00	0.00	0.00	2145.
1.01	14.00	14	.24	.16	.07	63.	1.05	18.00	114	0.00	0.00	0.00	1991.
1.01	15.00	15	.30	.23	.07	109.	1.05	19.00	115	0.00	0.00	0.00	1846.
1.01	16.00	16	.75	.64	.10	196.	1.05	20.00	116	0.00	0.00	0.00	1709.
1.01	17.00	17	.28	.25	.03	314.	1.05	21.00	117	0.00	0.00	0.00	1583.
1.01	18.00	18	.22	.20	.02	485.	1.05	22.00	118	0.00	0.00	0.00	1467.
1.01	19.00	19	.03	.02	.00	688.	1.05	23.00	119	0.00	0.00	0.00	1358.
1.01	20.00	20	.03	.02	.00	930.	1.06	0.00	120	0.00	0.00	0.00	1257.
1.01	21.00	21	.03	.02	.00	1203.	1.06	1.00	121	0.00	0.00	0.00	1164.
1.01	22.00	22	.03	.02	.00	1514.	1.06	2.00	122	0.00	0.00	0.00	1081.
1.01	23.00	23	.03	.02	.00	1863.	1.06	3.00	123	0.00	0.00	0.00	1006.
1.02	0.00	24	.03	.02	.00	2253.	1.06	4.00	124	0.00	0.00	0.00	936.
1.02	1.00	25	.16	.15	.01	2691.	1.06	5.00	125	0.00	0.00	0.00	871.
1.02	2.00	26	.16	.15	.01	3159.	1.06	6.00	126	0.00	0.00	0.00	814.
1.02	3.00	27	.16	.15	.01	3664.	1.06	7.00	127	0.00	0.00	0.00	808.
1.02	4.00	28	.16	.16	.01	4176.	1.06	8.00	128	0.00	0.00	0.00	808.
1.02	5.00	29	.16	.16	.01	4673.	1.06	9.00	129	0.00	0.00	0.00	808.
1.02	6.00	30	.16	.16	.01	5155.	1.06	10.00	130	0.00	0.00	0.00	808.
1.02	7.00	31	.73	.71	.02	5619.	1.06	11.00	131	0.00	0.00	0.00	808.
1.02	8.00	32	.73	.72	.02	6094.	1.06	12.00	132	0.00	0.00	0.00	808.
1.02	9.00	33	.73	.72	.01	6584.	1.06	13.00	133	0.00	0.00	0.00	808.
1.02	10.00	34	.73	.72	.01	7124.	1.06	14.00	134	0.00	0.00	0.00	808.
1.02	11.00	35	.73	.73	.01	7713.	1.06	15.00	135	0.00	0.00	0.00	808.
1.02	12.00	36	.73	.73	.01	8377.	1.06	16.00	136	0.00	0.00	0.00	808.
1.02	13.00	37	1.86	1.85	.02	9183.	1.06	17.00	137	0.00	0.00	0.00	808.
1.02	14.00	38	2.23	2.22	.01	10162.	1.06	18.00	138	0.00	0.00	0.00	808.
1.02	15.00	39	2.79	2.78	.01	11406.	1.06	19.00	139	0.00	0.00	0.00	808.
1.02	16.00	40	7.08	7.06	.02	13146.	1.06	20.00	140	0.00	0.00	0.00	808.
1.02	17.00	41	2.61	2.60	.00	15260.	1.06	21.00	141	0.00	0.00	0.00	808.
1.02	18.00	42	2.05	2.05	.00	17983.	1.06	22.00	142	0.00	0.00	0.00	808.
1.02	19.00	43	.25	.24	.00	21088.	1.06	23.00	143	0.00	0.00	0.00	808.
1.02	20.00	44	.25	.24	.00	24600.	1.07	0.00	144	0.00	0.00	0.00	808.
1.02	21.00	45	.25	.24	.00	28414.	1.07	1.00	145	0.00	0.00	0.00	808.
1.02	22.00	46	.25	.24	.00	32577.	1.07	2.00	146	0.00	0.00	0.00	808.
1.02	23.00	47	.25	.24	.00	37068.	1.07	3.00	147	0.00	0.00	0.00	808.
1.03	0.00	48	.25	.24	.00	41890.	1.07	4.00	148	0.00	0.00	0.00	808.
1.03	1.00	49	0.00	0.00	0.00	47036.	1.07	5.00	149	0.00	0.00	0.00	808.
1.03	2.00	50	0.00	0.00	0.00	52292.	1.07	6.00	150	0.00	0.00	0.00	808.
1.03	3.00	51	0.00	0.00	0.00	57668.	1.07	7.00	151	0.00	0.00	0.00	808.

1.03	4.00	52	0.00	0.00	0.00	62787.	1.07	8.00	152	0.00	0.00	0.00	808.
1.03	5.00	53	0.00	0.00	0.00	67412.	1.07	9.00	153	0.00	0.00	0.00	808.
1.03	6.00	54	0.00	0.00	0.00	71530.	1.07	10.00	154	0.00	0.00	0.00	808.
1.03	7.00	55	0.00	0.00	0.00	74778.	1.07	11.00	155	0.00	0.00	0.00	808.
1.03	8.00	56	0.00	0.00	0.00	77430.	1.07	12.00	156	0.00	0.00	0.00	808.
1.03	9.00	57	0.00	0.00	0.00	79213.	1.07	13.00	157	0.00	0.00	0.00	808.
1.03	10.00	58	0.00	0.00	0.00	80396.	1.07	14.00	158	0.00	0.00	0.00	808.
1.03	11.00	59	0.00	0.00	0.00	80836.	1.07	15.00	159	0.00	0.00	0.00	808.
1.03	12.00	60	0.00	0.00	0.00	80698.	1.07	16.00	160	0.00	0.00	0.00	808.
1.03	13.00	61	0.00	0.00	0.00	80006.	1.07	17.00	161	0.00	0.00	0.00	808.
1.03	14.00	62	0.00	0.00	0.00	78838.	1.07	18.00	162	0.00	0.00	0.00	808.
1.03	15.00	63	0.00	0.00	0.00	77153.	1.07	19.00	163	0.00	0.00	0.00	808.
1.03	16.00	64	0.00	0.00	0.00	74900.	1.07	20.00	164	0.00	0.00	0.00	808.
1.03	17.00	65	0.00	0.00	0.00	72318.	1.07	21.00	165	0.00	0.00	0.00	808.
1.03	18.00	66	0.00	0.00	0.00	69462.	1.07	22.00	166	0.00	0.00	0.00	808.
1.03	19.00	67	0.00	0.00	0.00	66454.	1.07	23.00	167	0.00	0.00	0.00	808.
1.03	20.00	68	0.00	0.00	0.00	63264.	1.08	0.00	168	0.00	0.00	0.00	808.
1.03	21.00	69	0.00	0.00	0.00	59943.	1.08	1.00	169	0.00	0.00	0.00	808.
1.03	22.00	70	0.00	0.00	0.00	56372.	1.08	2.00	170	0.00	0.00	0.00	808.
1.03	23.00	71	0.00	0.00	0.00	52697.	1.08	3.00	171	0.00	0.00	0.00	808.
1.04	0.00	72	0.00	0.00	0.00	48883.	1.08	4.00	172	0.00	0.00	0.00	808.
1.04	1.00	73	0.00	0.00	0.00	45099.	1.08	5.00	173	0.00	0.00	0.00	808.
1.04	2.00	74	0.00	0.00	0.00	41533.	1.08	6.00	174	0.00	0.00	0.00	808.
1.04	3.00	75	0.00	0.00	0.00	38228.	1.08	7.00	175	0.00	0.00	0.00	808.
1.04	4.00	76	0.00	0.00	0.00	35254.	1.08	8.00	176	0.00	0.00	0.00	808.
1.04	5.00	77	0.00	0.00	0.00	32599.	1.08	9.00	177	0.00	0.00	0.00	808.
1.04	6.00	78	0.00	0.00	0.00	30162.	1.08	10.00	178	0.00	0.00	0.00	808.
1.04	7.00	79	0.00	0.00	0.00	27930.	1.08	11.00	179	0.00	0.00	0.00	808.
1.04	8.00	80	0.00	0.00	0.00	25851.	1.08	12.00	180	0.00	0.00	0.00	808.
1.04	9.00	81	0.00	0.00	0.00	23969.	1.08	13.00	181	0.00	0.00	0.00	808.
1.04	10.00	82	0.00	0.00	0.00	22222.	1.08	14.00	182	0.00	0.00	0.00	808.
1.04	11.00	83	0.00	0.00	0.00	20688.	1.08	15.00	183	0.00	0.00	0.00	808.
1.04	12.00	84	0.00	0.00	0.00	19254.	1.08	16.00	184	0.00	0.00	0.00	808.
1.04	13.00	85	0.00	0.00	0.00	17914.	1.08	17.00	185	0.00	0.00	0.00	808.
1.04	14.00	86	0.00	0.00	0.00	16626.	1.08	18.00	186	0.00	0.00	0.00	808.
1.04	15.00	87	0.00	0.00	0.00	15426.	1.08	19.00	187	0.00	0.00	0.00	808.
1.04	16.00	88	0.00	0.00	0.00	14300.	1.08	20.00	188	0.00	0.00	0.00	808.
1.04	17.00	89	0.00	0.00	0.00	13243.	1.08	21.00	189	0.00	0.00	0.00	808.
1.04	18.00	90	0.00	0.00	0.00	12245.	1.08	22.00	190	0.00	0.00	0.00	808.
1.04	19.00	91	0.00	0.00	0.00	11335.	1.08	23.00	191	0.00	0.00	0.00	808.
1.04	20.00	92	0.00	0.00	0.00	10520.	1.09	0.00	192	0.00	0.00	0.00	808.
1.04	21.00	93	0.00	0.00	0.00	9764.	1.09	1.00	193	0.00	0.00	0.00	808.
1.04	22.00	94	0.00	0.00	0.00	9056.	1.09	2.00	194	0.00	0.00	0.00	808.
1.04	23.00	95	0.00	0.00	0.00	8386.	1.09	3.00	195	0.00	0.00	0.00	808.
1.05	0.00	96	0.00	0.00	0.00	7781.	1.09	4.00	196	0.00	0.00	0.00	808.
1.05	1.00	97	0.00	0.00	0.00	7214.	1.09	5.00	197	0.00	0.00	0.00	808.
1.05	2.00	98	0.00	0.00	0.00	6684.	1.09	6.00	198	0.00	0.00	0.00	808.
1.05	3.00	99	0.00	0.00	0.00	6181.	1.09	7.00	199	0.00	0.00	0.00	808.
1.05	4.00	100	0.00	0.00	0.00	5728.	1.09	8.00	200	0.00	0.00	0.00	808.

SUM 28.17 27.16 1.02 2427504.
(716.)(690.)(26.)(74402.[illegible])

	PEAK	6 HOUR	24 HOUR	72 HOUR	TOTAL VOLUME
CFS	80836.	77801.	67975.	34475.	2427128.
CMS	2289.	2203.	1925.	976.	74392.
INCHES		5.05	17.21	26.18	27.71
MM		128.40	437.04	664.96	703.78
AC FT		[illegible]	134827.	205140.	217118.
THOUS CU M		[illegible]	166307.	253037.	267811.

PLATE D-9

HYDROGRAPH AT STA000001 FOR PLAN 1, RTIO 1

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	40413.	39940.	[illegible]	17,?37.	[illegible]
CMS	1145.	1131.	962.	486.	[illegible]
INCHES		2.53	8.60	13.09	13.85
MM		64.20	218.52	332.48	351.89
AC-FT		19805.	67414.	102570.	108559.
THOUS CU M		24429.	83153.	126518.	133906.

HYDROGRAPH AT STA000001 FOR PLAN 1, RTIO 2

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	80836.	79881.	67975.	34475.	2627128.
CMS	2289.	2262.	1925.	976.	74392.
INCHES		5.05	17.21	26.18	27.71
MM		128.40	437.04	664.96	703.78
AC-FT		39610.	134827.	205140.	217118.
THOUS CU M		48859.	166307.	253037.	267811.

********** ********** ********** ********** **********

HYDROGRAPH ROUTING

ROUTED FLOWS THROUGH RESERVOIR 10134

	ISTAQ	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME	ISTAGE	IAUTO
	000002	1	0	0	2	0	1	0	0

ROUTING DATA

QLOSS	CLOSS	AVG	IRES	ISAME	IOPT	IPMP		LSTR
0.0	0.000	0.00	1	1	0	0		0

NSTPS	NSTDL	LAG	AMSKK	X	TSK	STORA	ISPRAT
1	0	0	0.000	0.000	0.000	-709.	-1

STAGE	709.00	710.00	712.00	713.00	714.00	716.00	717.00	718.00	720.00	722.00
	724.00	726.00	728.00	730.00	732.00	734.00	736.00	737.00	738.00	740.00
FLOW	0.00	120.00	588.00	901.00	1256.00	1895.00	1917.00	2089.00	2632.00	3574.00
	4575.00	5730.00	7145.00	8684.00	10472.00	12359.00	14396.00	15440.00	16583.00	18918.00

CAPACITY=	0.	256.	6524.	25598.	56328.	60690.	69948.	79901.	90665.	96885.
	102350.	115071.	128841.	143584.	159281.	175911.	193454.	284000.		
ELEVATION=	670.	680.	690.	700.	709.	710.	712.	714.	716.	717.
	718.	720.	722.	724.	726.	728.	730.	740.		

CREL	SPWID	COQW	EXPW	ELEVL	COQL	CAREA	EXPL
709.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DAM DATA

TOPEL	COQD	EXPD	DAMWID
737.4	2.9	1.5	2550.

CREST LENGTH	0.	615.	1830.	2235.	2370.	2630.	2660.	2685.	2710.	2735.

PLATE D-10

[illegible]
STATION [illegible]

STATION 000007, PLAN 1, RATIO 1 0.50 PMF

END-OF-PERIOD HYDROGRAPH ORDINATES

OUTFLOW

8.	8.	8.	8.	8.	8.	8.	8.	8.	8.
8.	8.	8.	8.	8.	8.	8.	9.	9.	10.
11.	13.	14.	17.	19.	22.	26.	30.	35.	40.
45.	51.	58.	65.	73.	81.	90.	100.	112.	139.
158.	192.	232.	278.	332.	395.	465.	547.	648.	773.
[illegible]	1085.	1260.	1431.	1603.	1782.	1900.	1912.	1968.	2059.
2179.	2312.	2441.	2566.	2715.	2890.	3056.	3212.	3360.	3497.
[illegible]	3760.	3874.	3978.	4071.	4154.	4226.	4295.	4355.	4407.
4454.	4495.	4531.	4563.	4592.	4617.	4637.	4654.	4668.	4679.
4686.	4691.	4693.	4693.	4691.	4687.	4681.	4674.	4665.	4655.
4643.	4630.	4617.	4602.	4586.	4569.	4553.	4536.	4518.	4500.
4482.	4463.	4443.	4423.	4403.	4383.	4362.	4341.	4320.	4299.
4277.	4256.	4234.	4212.	4190.	4168.	4147.	4125.	4103.	4082.
4060.	4039.	4018.	3997.	3976.	3955.	3934.	3914.	3893.	3873.
3853.	3833.	3813.	3793.	3773.	3754.	3734.	3715.	3696.	3677.
3657.	3639.	3620.	3601.	3582.	3564.	3546.	3527.	3510.	3494.
3477.	3461.	3445.	3429.	3413.	3396.	3381.	3365.	3349.	3333.
3318.	3302.	3287.	3271.	3256.	3241.	3226.	3211.	3196.	3181.
3166.	3151.	3136.	3122.	3107.	3093.	3079.	3064.	3050.	3036.
3022.	3008.	2994.	2980.	2966.	2953.	2939.	2926.	2912.	2899.

STORAGE

56327.	56327.	56326.	56325.	56325.	56324.	56324.	56323.	56322.	56322.
56322.	56321.	56322.	56323.	56326.	56332.	56341.	56357.	56381.	56413.
56456.	56512.	56580.	56664.	56765.	56884.	57023.	57183.	57363.	57568.
57782.	58020.	58277.	58555.	58855.	59181.	59536.	59927.	60363.	60880.
61435.	62108.	62897.	63820.	64890.	66120.	67524.	69113.	70901.	72895.
75097.	77503.	80096.	82855.	85753.	88757.	91842.	94981.	98152.	101423.
104449.	107565.	110592.	113526.	116350.	119048.	121610.	124031.	126305.	128475.
130384.	132177.	133803.	135269.	136584.	137763.	138818.	139762.	140604.	141352.
142014.	142597.	143109.	143557.	143946.	144279.	144559.	144789.	144973.	145114.
145214.	145278.	145309.	145310.	145283.	145229.	145152.	145052.	144932.	144793.
144637.	144465.	144279.	144079.	143867.	143645.	143413.	143172.	142923.	142667.
142404.	142134.	141859.	141579.	141294.	141005.	140712.	140416.	140116.	139815.
139510.	139204.	138897.	138588.	138278.	137968.	137658.	137350.	137043.	136738.
136435.	136134.	135835.	135537.	135241.	134946.	134654.	134363.	134074.	133786.
133500.	133216.	132934.	132653.	132373.	132096.	131820.	131545.	131272.	131001.
130732.	130463.	130197.	129932.	129669.	129407.	129146.	128887.	128631.	128376.
128122.	127870.	127619.	127369.	127120.	126873.	126627.	126382.	126138.	125896.
125655.	125415.	125176.	124937.	124703.	124468.	124234.	124002.	123771.	123541.
123312.	123084.	122858.	122633.	122409.	122186.	121964.	121744.	121525.	121307.
121090.	120874.	120659.	120446.	120234.	120022.	119812.	119603.	119396.	119189.

STAGE

709.0	709.0	709.0	709.0	709.0	709.0	709.0	709.0	709.0	709.0
709.0	709.0	709.0	709.0	709.0	709.0	709.0	709.0	709.0	709.0
709.0	709.0	709.1	709.1	709.1	709.1	709.2	709.2	709.2	709.3
709.3	709.4	709.4	709.5	709.6	709.7	709.7	709.8	709.9	710.0
710.2	710.3	710.5	710.7	710.9	711.2	711.5	711.8	712.2	712.6
713.0	713.5	714.0	714.5	715.1	715.6	716.2	716.8	717.3	717.8
718.3	718.8	719.3	719.8	720.2	720.6	720.9	721.3	721.6	721.9
722.2	722.5	722.7	722.9	723.1	723.2	723.4	723.5	723.6	723.7
723.8	723.9	723.9	724.0	724.0	724.1	724.1	724.2	724.2	724.2
724.2	724.2	724.2	724.2	724.2	724.2	724.2	724.2	724.2	724.2

724.1	724.1	724.1	724.1	724.0	724.0	724.0	723.9	723.9	723.9
723.8	723.8	723.8	723.7	723.7	723.7	723.6	723.6	723.5	723.5
723.4	723.4	723.4	723.3	723.3	723.2	723.2	723.2	723.1	723.1
723.0	723.0	722.9	722.9	722.9	722.8	722.8	722.7	722.7	722.7
722.6	722.6	722.6	722.5	722.5	722.4	722.4	722.4	722.3	722.3
722.3	722.2	722.2	722.1	722.1	722.1	722.0	722.0	722.0	721.9
721.9	721.9	721.8	721.8	721.8	721.7	721.7	721.6	721.6	721.6
721.5	721.5	721.5	721.4	721.4	721.4	721.3	721.3	721.3	721.2
721.2	721.2	721.1	721.1	721.1	721.0	721.0	721.0	720.9	720.9
720.9	720.8	720.8	720.8	720.7	720.7	720.7	720.7	720.6	720.6

PEAK OUTFLOW IS 4693. AT TIME 94.00 HOURS

	PEAK	6 HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	4693.	4690.	4642.	4340.	553019.
CMS	133.	133.	131.	123.	15660.
INCHES		.30	1.18	3.30	5.83
MM		7.54	29.85	83.71	148.15
AC-FT		2326.	9208.	25824.	45704.
THOUS CU M		2868.	11358.	31854.	56375.

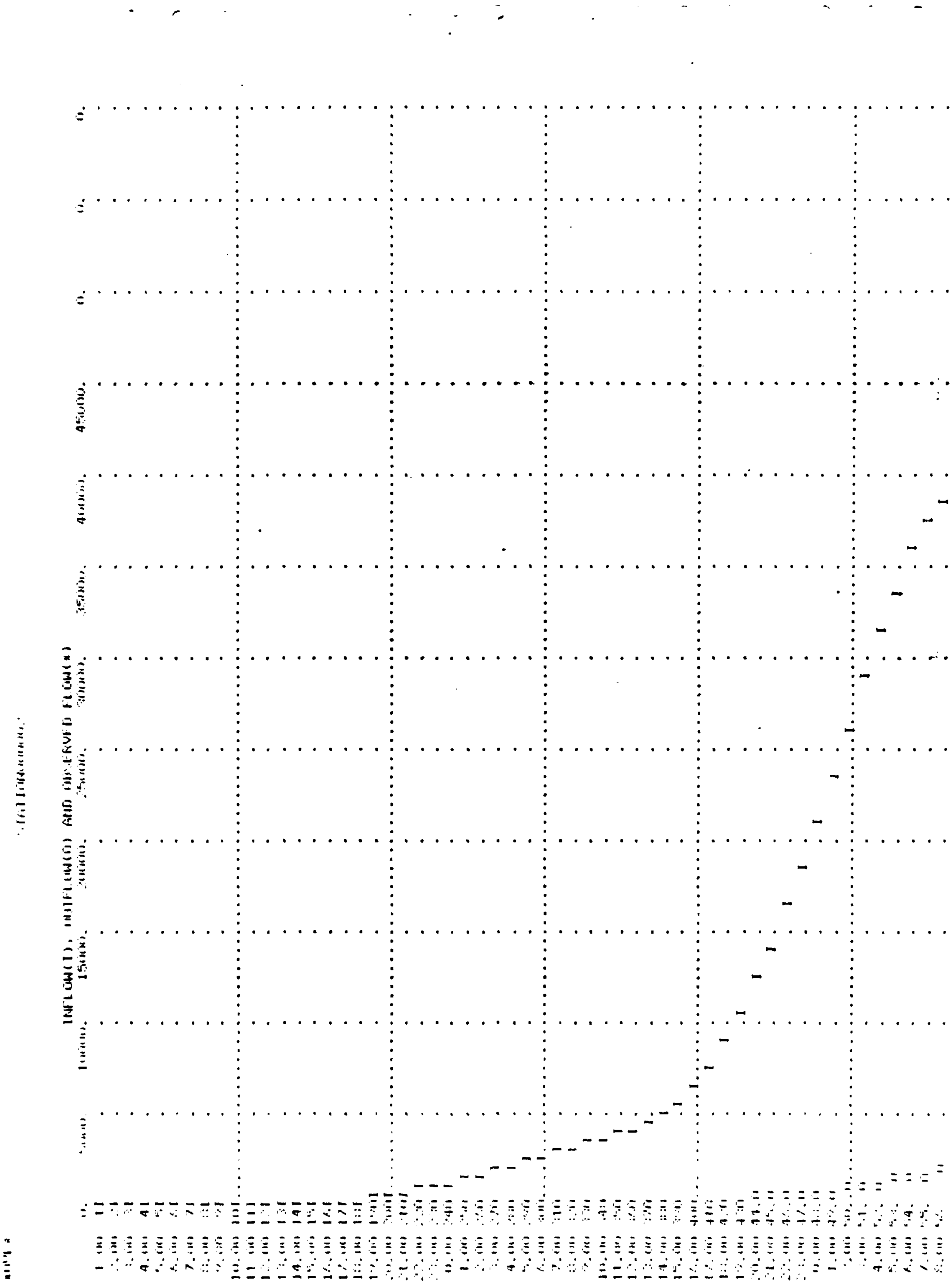

INFLOW(I), OUTFLOW(O) AND OBSERVED FLOW(*)
0.
5000.
10000.
15000.
20000.
25000.
30000.
35000.
40000.
45000.

PLATE D-13

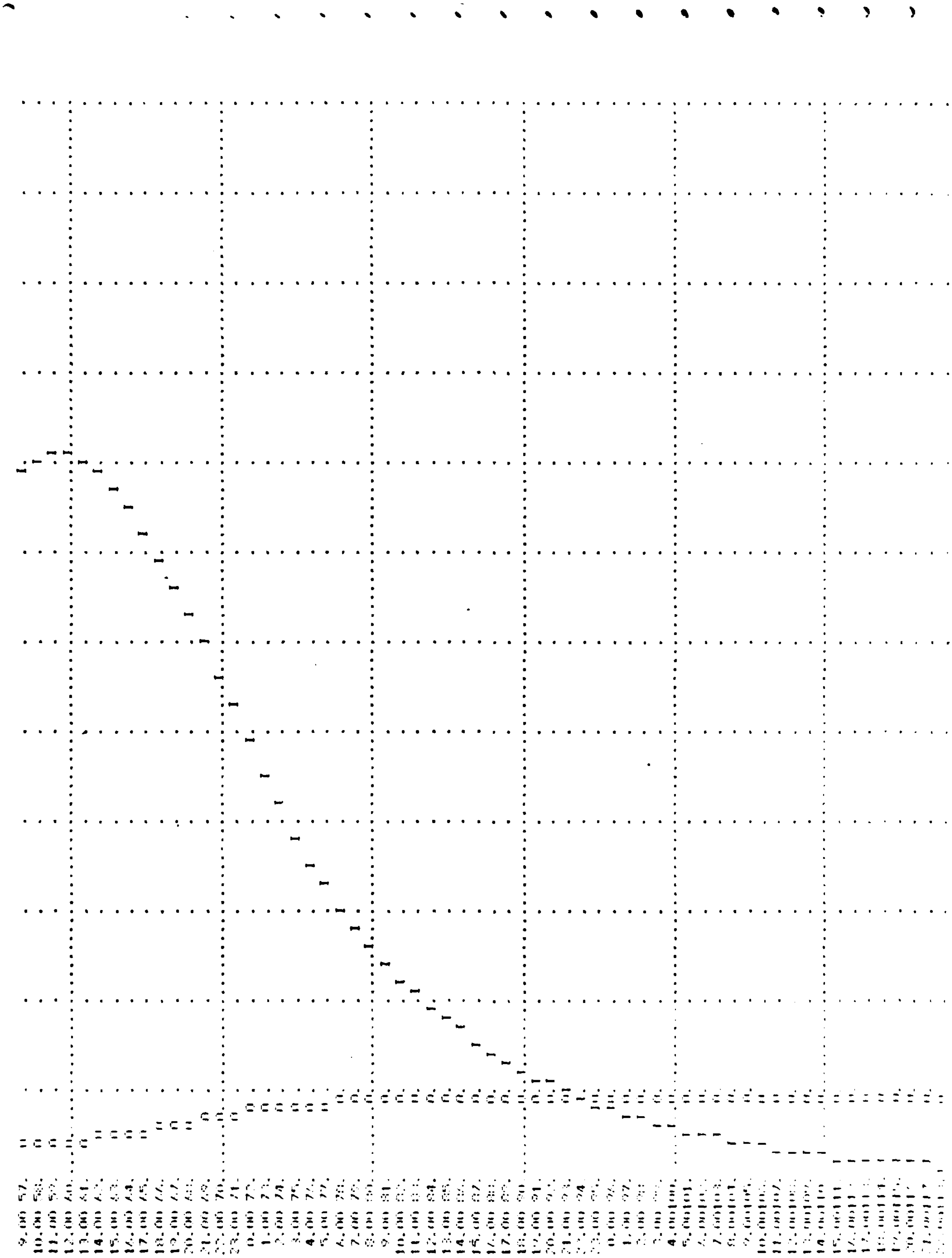


PLATE D-14

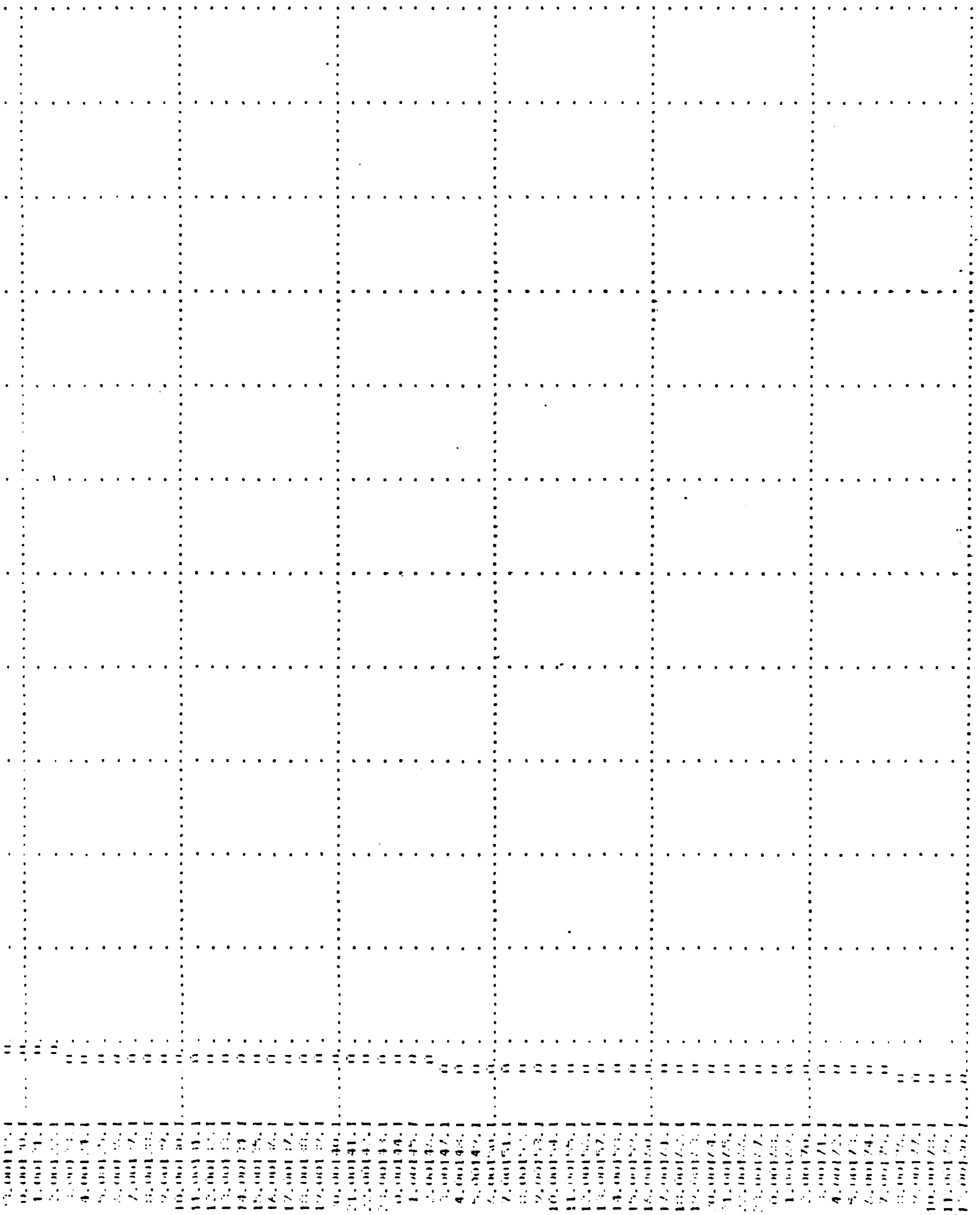


PLATE D-15

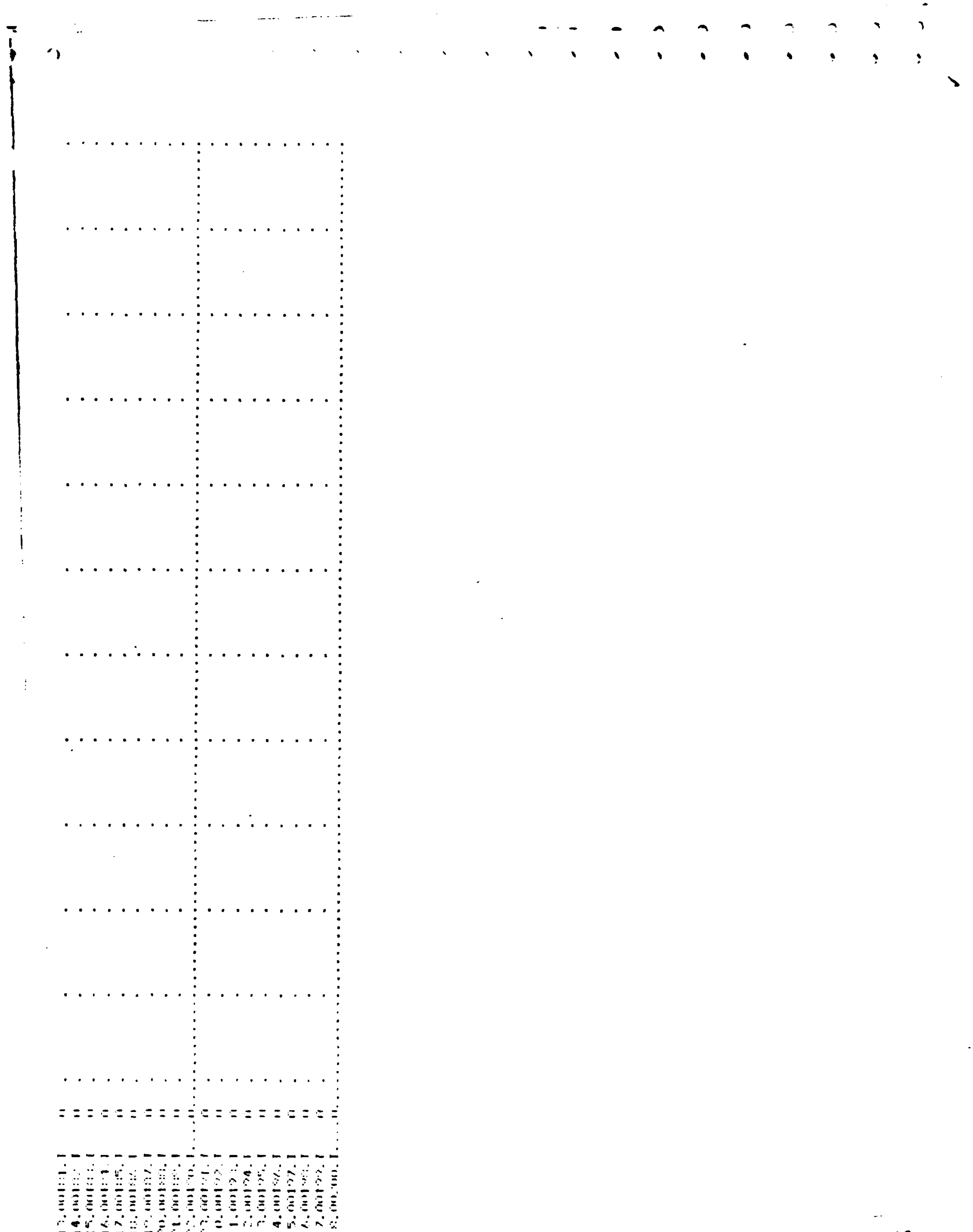


PLATE D-16

STATION 00002, PLAN 1, RATIO 2 PMF

END OF PERIOD HYDROGRAPH ORDINATES

OUTFLOW

8.	8.	8.	8.	8.	8.	8.	8.	8.	8.
8.	8.	8.	8.	8.	8.	9.	10.	11.	13.
15.	18.	21.	26.	31.	37.	44.	52.	62.	72.
83.	95.	109.	126.	156.	189.	225.	264.	308.	358.
416.	483.	563.	672.	806.	968.	1167.	1389.	1580.	1815.
1907.	1979.	2148.	2385.	2636.	3028.	3430.	3866.	4313.	4768.
5230.	5683.	6183.	6673.	7142.	7602.	8038.	8449.	8851.	9252.
9620.	9955.	10256.	10527.	10779.	11001.	11198.	11371.	11523.	11654.
11798.	11865.	11947.	12016.	12073.	12117.	12151.	12174.	12188.	12192.
12187.	12178.	12161.	12137.	12108.	12073.	12034.	11990.	11943.	11891.
11837.	11779.	11719.	11656.	11591.	11524.	11455.	11384.	11313.	11240.
11145.	11090.	11014.	10938.	10860.	10782.	10704.	10625.	10546.	10467.
10392.	10317.	10241.	10166.	10091.	10016.	9941.	9867.	9793.	9720.
9648.	9576.	9505.	9434.	9364.	9294.	9225.	9157.	9089.	9022.
8955.	8889.	8823.	8758.	8693.	8635.	8579.	8523.	8467.	8412.
8357.	8302.	8248.	8195.	8141.	8088.	8036.	7983.	7932.	7880.
7829.	7778.	7728.	7678.	7628.	7579.	7530.	7482.	7433.	7386.
7338.	7291.	7244.	7198.	7151.	7107.	7063.	7019.	6976.	6933.
6890.	6847.	6805.	6763.	6721.	6680.	6639.	6598.	6557.	6517.
6477.	6437.	6398.	6359.	6320.	6281.	6243.	6205.	6167.	6129.

STORAGE

56327.	56327.	56326.	56325.	56325.	56324.	56324.	56323.	56322.	56322.
56322.	56322.	56324.	56327.	56334.	56345.	56366.	56398.	56446.	56512.
56599.	56709.	56847.	57016.	57218.	57456.	57735.	58055.	58416.	58816.
59254.	59730.	60245.	60802.	61404.	62054.	62763.	63542.	64409.	65396.
66538.	67875.	69446.	71283.	73413.	75860.	78649.	81807.	85360.	89324.
93715.	98532.	103741.	109295.	115134.	121189.	127395.	133689.	140014.	146313.
152541.	158654.	164609.	170361.	175874.	181123.	186093.	190772.	195148.	199207.
202934.	204322.	209371.	212092.	214507.	216644.	218530.	220191.	221646.	222910.
224001.	224933.	225722.	226382.	226923.	227351.	227672.	227896.	228027.	228073.
228040.	227936.	227768.	227542.	227261.	226930.	226553.	226135.	225677.	225185.
224660.	224107.	223527.	222923.	222298.	221655.	220995.	220319.	219630.	218929.
218218.	217497.	216768.	216032.	215289.	214542.	213790.	213035.	212277.	211516.
210754.	209991.	209228.	208465.	207703.	206942.	206184.	205432.	204687.	203947.
203214.	202486.	201765.	201049.	200339.	199635.	198936.	198243.	197556.	196875.
196197.	195528.	194863.	194203.	193549.	192900.	192256.	191617.	190982.	190352.
189726.	189104.	188487.	187875.	187267.	186663.	186063.	185468.	184878.	184291.
183707.	183131.	182557.	181987.	181421.	180859.	180302.	179748.	179199.	178653.
178112.	177574.	177040.	176510.	175984.	175463.	174945.	174431.	173921.	173414.
172910.	172410.	171913.	171419.	170929.	170443.	169959.	169479.	169002.	168529.
168059.	167592.	167128.	166668.	166211.	165757.	165306.	164859.	164415.	163973.

STAGE

709.0	709.0	709.0	709.0	709.0	709.0	709.0	709.0	709.0	709.0
709.0	709.0	709.0	709.0	709.0	709.0	709.0	709.0	709.0	709.0
709.1	709.1	709.1	709.2	709.2	709.3	709.3	709.4	709.5	709.6
709.7	709.8	709.9	710.0	710.2	710.3	710.4	710.6	710.8	711.0
711.3	711.6	711.9	712.3	712.7	713.2	713.7	714.4	715.0	715.8
716.5	717.4	718.2	719.1	720.0	720.9	721.8	722.7	723.5	724.3
725.1	725.9	726.6	727.3	728.0	728.6	729.2	729.7	730.2	730.6
731.0	731.4	731.8	732.1	732.3	732.6	732.8	733.0	733.1	733.3
733.4	733.5	733.6	733.6	733.7	733.7	733.8	733.8	733.8	733.8
733.8	733.8	733.8	733.8	733.7	733.7	733.7	733.6	733.6	733.5
733.4	733.4	733.3	733.3	733.2	733.1	733.0	733.0	732.9	732.8

732.7	732.7	732.6	732.5	732.4	732.3	732.2	732.2	732.1	732.0
731.9	731.8	731.7	731.7	731.6	731.5	731.4	731.3	731.2	731.2
731.1	731.0	730.9	730.8	730.8	730.7	730.6	730.5	730.5	730.4
730.3	730.2	730.2	730.1	730.0	729.9	729.9	729.8	729.7	729.6
729.6	729.5	729.4	729.4	729.3	729.2	729.2	729.1	729.0	729.0
728.9	728.8	728.8	728.7	728.6	728.6	728.5	728.4	728.4	728.3
728.3	728.2	728.1	728.1	728.0	727.9	727.9	727.8	727.8	727.7
727.6	727.6	727.5	727.5	727.4	727.3	727.3	727.2	727.2	727.1
727.1	727.0	726.9	726.9	726.8	726.8	726.7	726.7	726.6	726.6

PEAK OUTFLOW IS 12192. AT TIME 90.00 HOURS

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	12192.	12179.	12008.	10900.	1324717.
CMS	345.	345.	340.	309.	37512.
INCHES		.77	3.04	8.28	13.97
MM		19.58	77.20	210.23	354.88
AC-FT		6039.	23817.	64858.	109481.
THOUS CU M		7449.	29378.	80001.	135042.

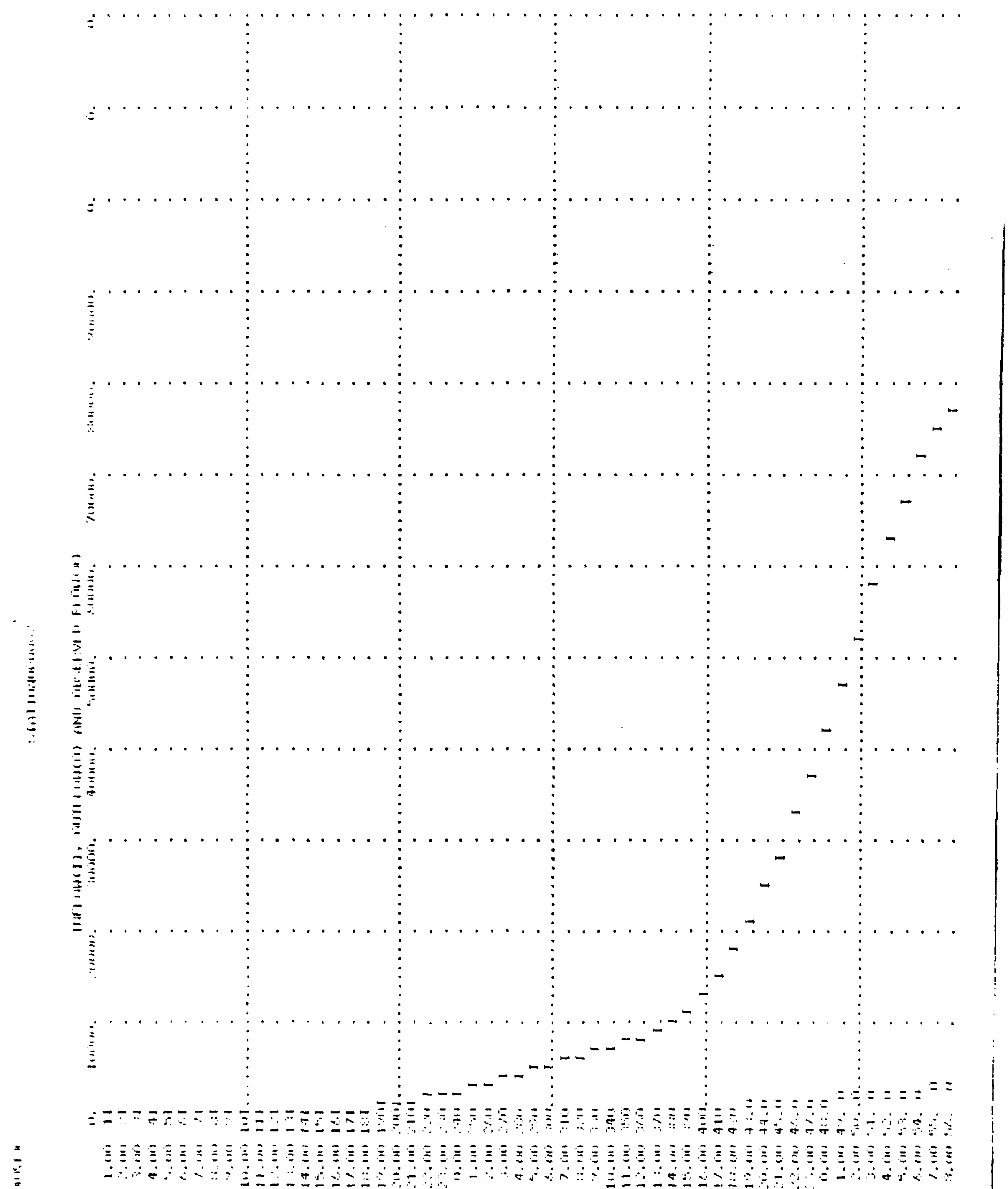


PLATE D-19

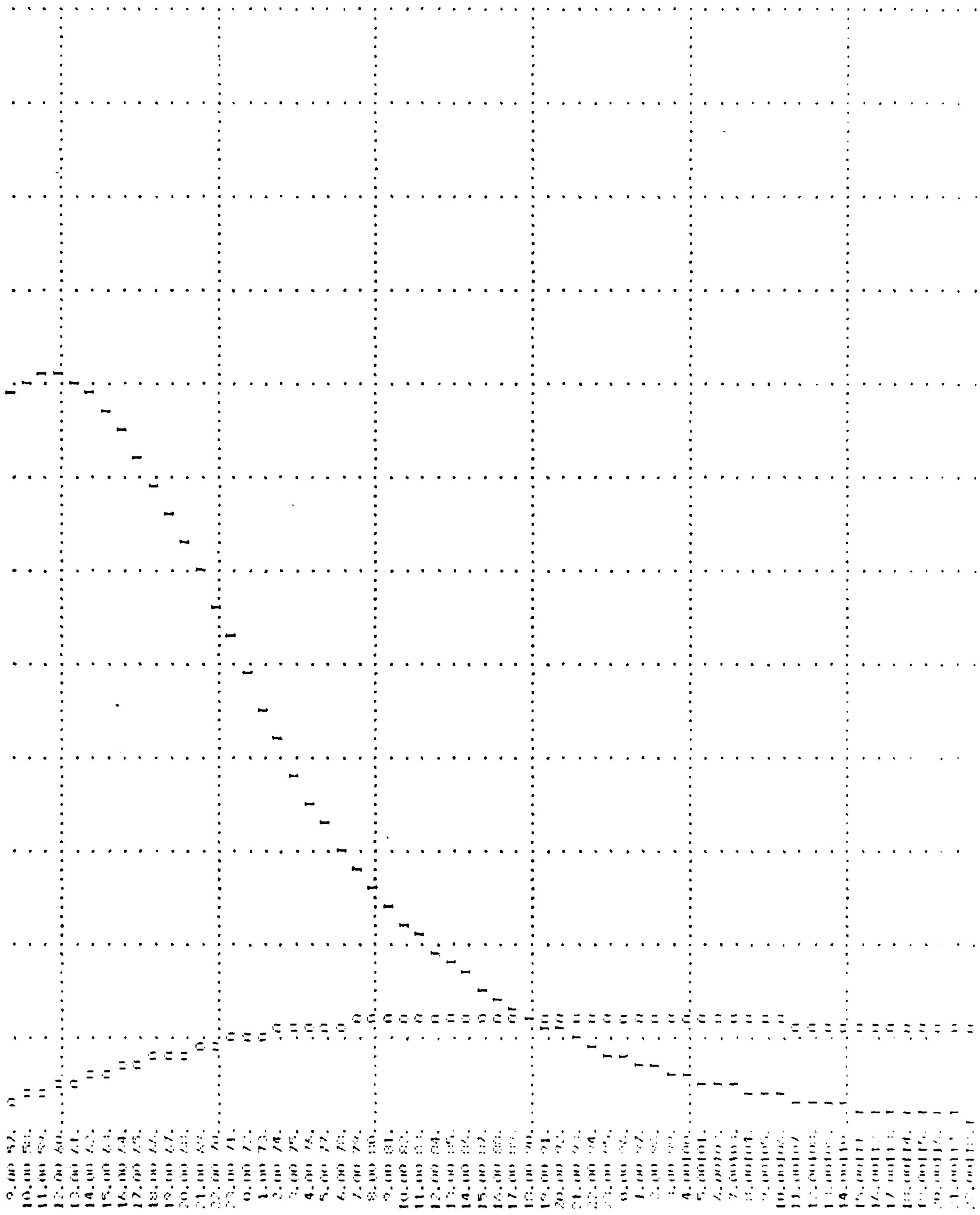


PLATE D-20

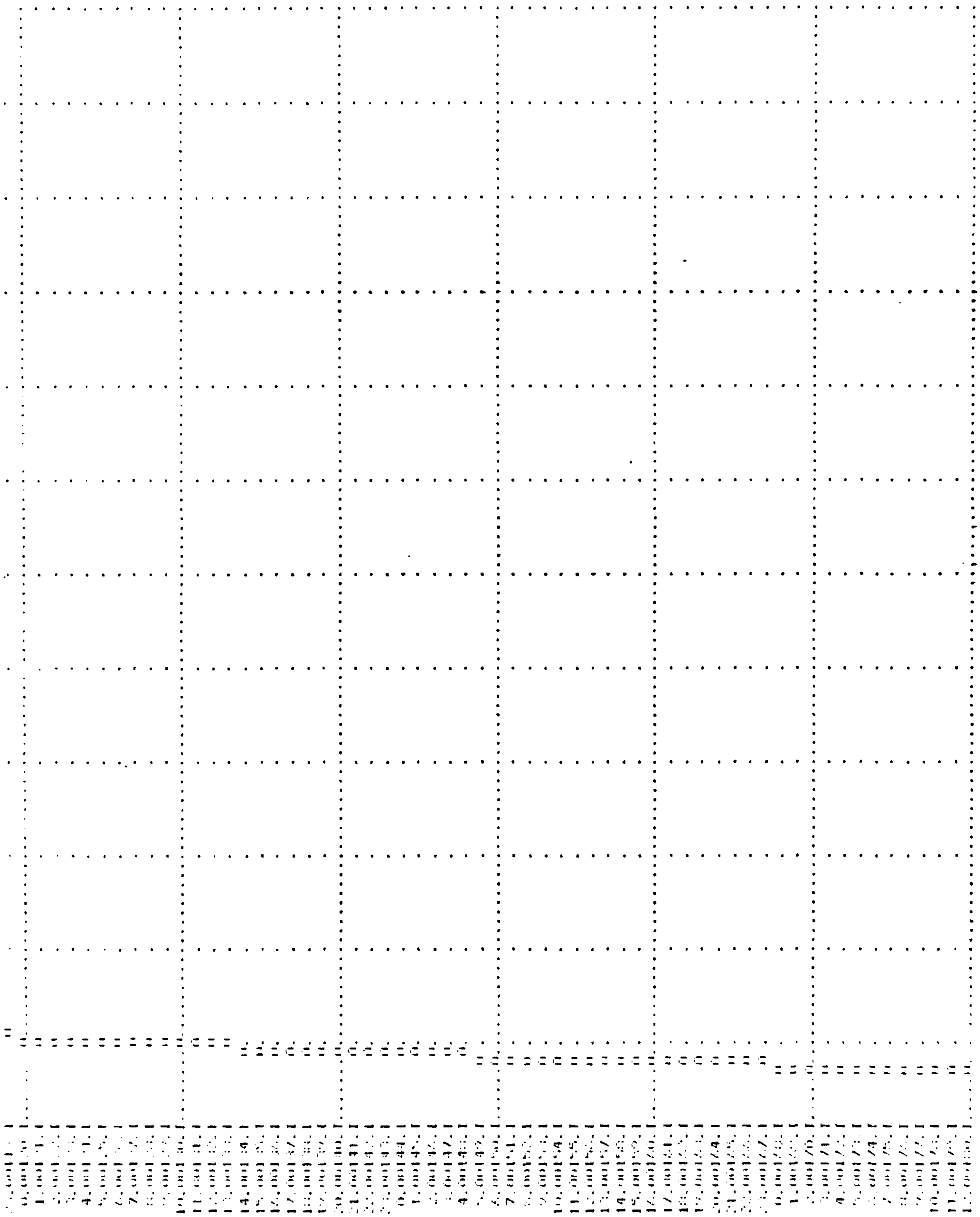


PLATE D-21

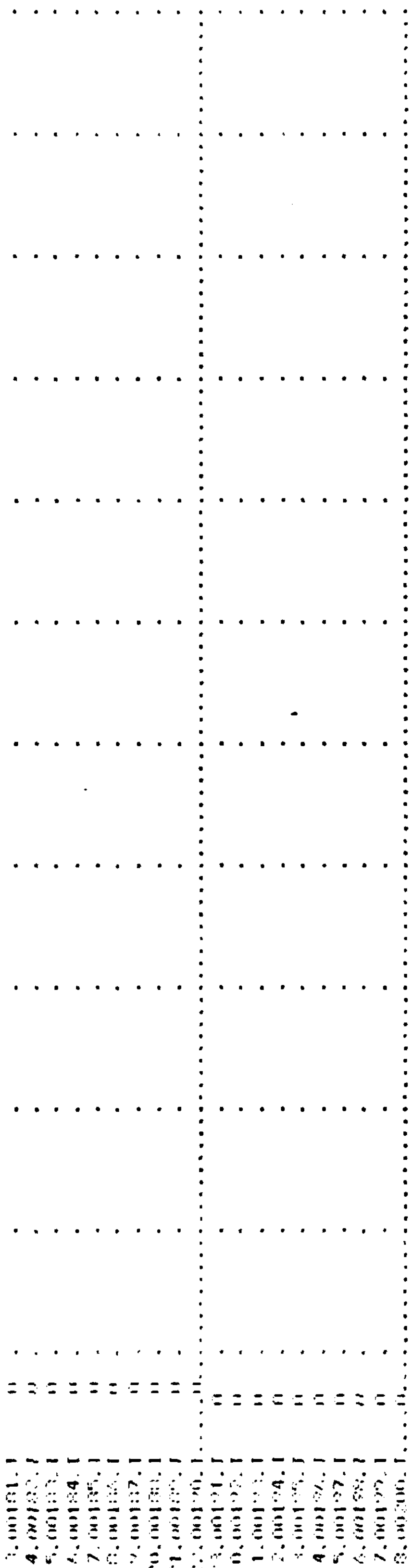


PLATE D-22

PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)
AREA IN SQUARE MILES (SQUARE KILOMETERS)

RATIOS APPLIED TO FLOWS

OPERATION	STATION	AREA	PLAN	RATIO 1 .50	RATIO 2 1.00
HYDROGRAPH AT	000001	147.00 (380.73)	1	40418. (1144.51)	80836. (2289.02)
ROUTED TO	000002	147.00 (380.73)	1	4693. (132.89)	12192. (345.25)

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	709.00	709.00	737.40
STORAGE	56328.	56328.	260458.
OUTFLOW	0.	8.	15897.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.50	724.22	0.00	145310.	4693.	0.00	94.00	0.00
1.00	733.82	0.00	228073.	12192.	0.00	90.00	0.00

HYDROLOGY REPORT
THOMAS HILL RESERVOIR

FOR

Associated Electric Cooperative
Missouri 73

1964

Prepared By

BURNS & McDONNELL ENGINEERING COMPANY
ENGINEERS ARCHITECTS CONSULTANTS
Kansas City, Missouri

63-701

SUMMARY OF

HYDROLOGY STUDIES

FOR

THOMAS HILL RESERVOIR

1. Scope of Report:
   a. Studies made by Burns & McDonnell Engineering Company for Associated Electric Cooperative, Springfield, Missouri.
   b. Dam to be earth fill dam for storage of cooling water for 150,000 kw steam generating plant with ultimate capacity of 500,000 kw.
   c. Dam to be located on the Middle Fork of the Chariton River in Section 24, T55N, R15W, in Randolph County, Missouri approximately two miles north of Thomas Hill, Missouri.

2. Design Criteria:
   a. Maximum probable storm - 23 inches of runoff in a 24 hour period.
      (1) Developed from depth-area-duration data from Hydrometeorological Report No. 33, "Seasonal Variation of the Probably Maximum Precipitation East of the 105th Meridian for Areas from 10 to 1,000 Square Miles and Durations of 6, 12, 24 and 48 hours."
   b. Project Storm - 12.23 inches of runoff in 24 hours.
      (1) Taken from "Review of Report on Chariton and Little Chariton Rivers and Tributaries" prepared by U. S. Army Engineer District, Kansas City, Corps of Engineers, dated March, 1963 as developed by the method described in Civil Engineering Bulletin No. 52-8.

3. Drainage Area Studies:
   a. Drainage Area - 147 square miles
      (1) Determined from planimetering U.S.G.S. maps covering the tributary basin.
   b. First studies were based on gaged flows on Chariton River at Keytesville and Prairie Hill, Missouri from 1929 through 1960. These were abandoned as not valid due to 10:1 ratio of tributary areas and other dissimilarities in drainage basin characteristics.
   c. Final studies were based on gaged flows on Medicine Creek at Galt, Missouri for period 1922 through 1960. Tributary basin was similar in shape and its size of 225 square miles was reasonably close to Middle Fork basin.

4. Storm Frequency:

a. Frequency Curve - Developed from U. S. Weather Bureau's Technical Paper No. 40, "Rainfall Frequency Atlas of the United States."

(1) Used 80% runoff for 6 hour period.

b. Runoffs:

Frequency (years)	Runoff (inches/6-hours)
25	3.6
100	4.4

c. Hydrographs - Routed through reservoir to determine frequency of discharge through chute spillway.

5. Inflow Hydrograph:

a. Synthetic Unit Hydrograph - Developed using "Mitchell Method" as detailed in "Unit Hydrographs in Illinois" by William D. Mitchell.

(1) Basic factor determined is the time lag (t) which is time in hours required for center of rainfall mass to reach center of runoff mass.

(2) Using t as determined by equation $t = 1.05A^{0.6}$, A being drainage area in square miles, synthetic unit hydrograph shown on Plate I was developed.

(3) Inflow hydrographs for various runoff values were developed from "Corps of Engineers Civil Engineering Bulletin No. 52-8" and inflow hydrograph for storm of 23 inches in 24 hours is shown as Curve I on Plate V in appendix.

(4) Project storm inflow hydrograph is shown as Curve I on Plate VI in appendix.

6. Reservoir Storage Capacity:

a. Area-Capacity-Curves - Developed from aerial topography of reservoir at scale of 1 inch to one thousand feet.

(1) Maps were planimetered at ten foot contour intervals to El. 730 and areas determined from these figures.

(2) Area - capacity curves shown on Plate II in appendix.

7. Outlet Structure:

a. Design Structure - Drop inlet connected to 9 foot circular tunnel discharging into concrete stilling basin under east dam abutment.

(1) Design drop inlet consists of 9 ft. by 18 ft. rectangular structure with two 18 ft. weirs, at El. 710 and concrete cover plates top of which is at El. 717. Has 8 inche cast iron pipe at El. 688 to maintain minimum flow below dam of 5 c.f.s. and 36 inches diameter sluice gate at El. 686.5 to permit lowering of lake for maintenance purposes.

(2) Hydraulic design is based on unpublished papers on results of model studies of this type of structure conducted by St. Anthony Falls Hydraulics Laboratory.

(3) Inlet will operate under weir flow conditions until reservoir rises to El. 715.75$\pm$. Above this outlet pipe will control the discharge.

(4) All outflow curves shown on plates in the appendix are based on the design drop inlet with cover plate constructed.

(5) Drop inlet modified to allow operation of reservoir at El. 712 or above to reduce pumping costs of cooling water.

(6) Removable stop logs have been placed on 18 ft. weirs to El. 712 and cover plate omitted, leaving support structure for cover plate to permit conversion to design conditions in the future.

(7) Modifications reduce maximum flow from structure to approximately 1500 c.f.s. at about El. 717.

(8) At El. 717 inlet will cycle between slug and weir flow; therefore discharge condition controlled by pipe flow will not be attained.

8. Spillway:

a. Chute type spillway 50 feet wide with concrete sill control section located west of earth fill dam.

(1) Spillway is set on rock with control section at El. 715 and discharging to natural rock channel after erosion of overburden.

b. Spillway will function as a weir with discharge computed by equation $Q=3.087\ Lh_c^{1.5}$ where:

(1) Q=Discharge in c.f.s.

(2) L= Length of weir crest in feet

(3) h_c= Head in feet above crest of weir.

c. Discharge curve for spillway is shown on Plate IV in appendix.

9. Flood Routing:

a. Maximum discharge and maximum elevation of various floods routed were determined from graphical routing curves.

(1) Determined by graphic methods outlined in U.S. Department of Agriculture, Soil Conservation Service, Washington, Mimeograph No. 3823, " Steps in the Graphic Routing of Floods Through Reservoirs."

(2) Routing of maximum probable storm shown on Plate V and routing of project storm is shown on Plate VI in appendix.

b. Reservoir elevation at the beginning of a given flood computed to be 713.0

(1) Determined by assuming full pool (El. 715) with no excessive inflow and outlet structure operating at design capacity for 5 days prior to start of flood routing.

c. Flood routing studies are summarized in Table below.

d. Lake elevations which would have been reached by peak floods each year of record are shown in Table B - Appendix.

FLOOD ROUTING RECORD

Storm	Max. Reservoir El.
Probable Maximum	
23" in 24 hours	731.70
Standard Project	
12.23" in 24 hours	724.20
25 yr. - 3.6" in 6 hours	714.50
100 yr. - 4.4" in 6 hours	715.50

10. Summary:

a. Hydrology studies using "design drop inlet" indicate maximum probable elevation attained by reservoir will be slightly below El. 732

b. With design drop inlet, freeboard on dam constructed to El. 737 will be 5 feet or greater.

c. Design outlet structure adequate to discharge flows in excess of 25 year frequency storm with no flow through chute spillway.

d. Modified drop inlet will have slightly less than half of flow of design drop inlet in elevation range below 715; with maximum probable discharge of about 1500 c.f.s.

e. Modified drop inlet will cause more frequent flooding downstream and more frequent discharge through chute spillway than design drop inlet.

f. Studies indicate that at least 4 foot of freeboard will be available even if maximum probable storm should occur prior to construction of cover plate on drop inlet.

g. Reservoir can be converted to provide greater flood protection if necessary.

APPENDIX

TABLE A

Unit Hydrograph Computations

$t = 1.05\ (A)^{0.6}$
$t = 1.05\ (147)^{0.6} = 1.05\ (20)$
$t = 21$ hrs.
$\Sigma q = \frac{A\ (Nd)}{0.03719} =$

$\Sigma q = \frac{147\ (5.7)}{.03719} =$

A = 147 sq. mi.

h_d = No. of ordinates /day
Computation interval
$= 0.2\ t = 0.2(21) = 4.2$ hrs.
$\therefore n_d = 24/4.2 = 5.7$
22,600 c.f.s.

Duration to Lag = 6/21 = 0.28

Form 80.20 - "Unit Hydrographs In Illinois"

Time (Lags)	Distribution (%)	Unit Hydrograph Ordinates (c.f.s.)	Actual Time (Hours)
0.2	4.17	940	6.3
.4	16.24	3,670	10.5
.6	20.06	4,540	14.7
.8	15.76	3,560	18.9
1.0	11.76	2,660	23.1
1.2	8.40	1,900	27.3
1.4	5.72	1,290	31.5
1.6	4.08	920	35.7
1.8	3.19	720	39.9
2.0	2.52	570	44.1
2.2	1.98	450	48.3
2.4	1.50	340	52.5
2.6	1.15	260	56.6
2.8	.98	220	60.9
3.0	.82	185	65.0
3.2	.66	149	69.2
3.4	.50	113	73.5
3.6	.30	68	77.6
3.8	.15	34	81.9
4.0	.06	14	86.0

TABLE B

Record Storms Medicine Creek

Converted Middle Fork

Storm	Max. Reservoir El.	Storm	Max. Reservoir El.
1960	714.0	1940	711.3
*1959	715.3	1939	711.6
1958	713.5	1938	710.4
1957	710.0	1937	712.6
1956	710.8	1936	710.8
1955	710.8	1935	713.5
1954	711.8	1934	710.2
1953	712.0	1933	711.5
1952	712.4	*1932	715.0
1951	713.7	1931	712.5
*1950	715.3	1930	711.5
1949	714.0	1929	712.0
1948	713.5	1928	712.9
*1947 (Max. Record)	717.4	1927	713.1
1946	713.3	1926	714.2
1945	714.7	1925	711.6
1944	712.6	1924	712.9
1943	713.6	1923	712.0
1942	714.2	1922	712.7
1941	714.2		

*Denotes reservoir elevation above 715 based on Design Drop Inlet.

TABLE B

Record Storms Medicine Creek

Converted Middle Fork

Storm	Max. Reservoir El.	Storm	Max. Reservoir El.
1960	714.0	1940	711.3
*1959	715.3	1939	711.6
1958	713.5	1938	710.4
1957	710.0	1937	712.6
1956	710.8	1936	710.8
1955	710.8	1935	713.5
1954	711.8	1934	710.2
1953	712.0	1933	711.5
1952	712.4	*1932	715.0
1951	713.7	1931	712.5
*1950	715.3	1930	711.5
1949	714.0	1929	712.0
1948	713.5	1928	712.9
*1947 (Max. Record)	717.4	1927	713.1
1946	713.3	1926	714.2
1945	714.7	1925	711.6
1944	712.6	1924	712.9
1943	713.6	1923	712.0
1942	714.2	1922	712.7
1941	714.2		

*Denotes reservoir elevation above 715 based on Design Drop Inlet.

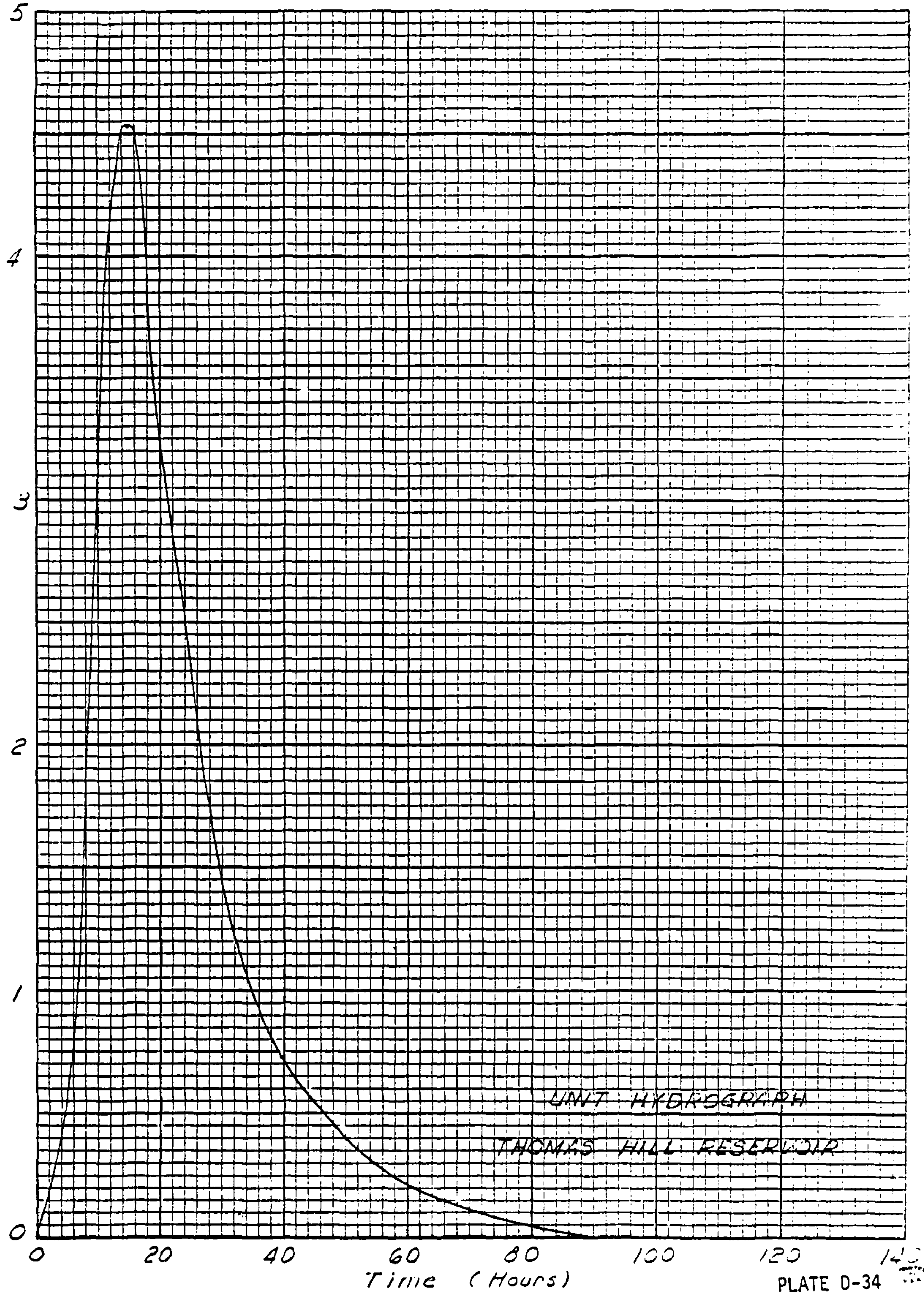
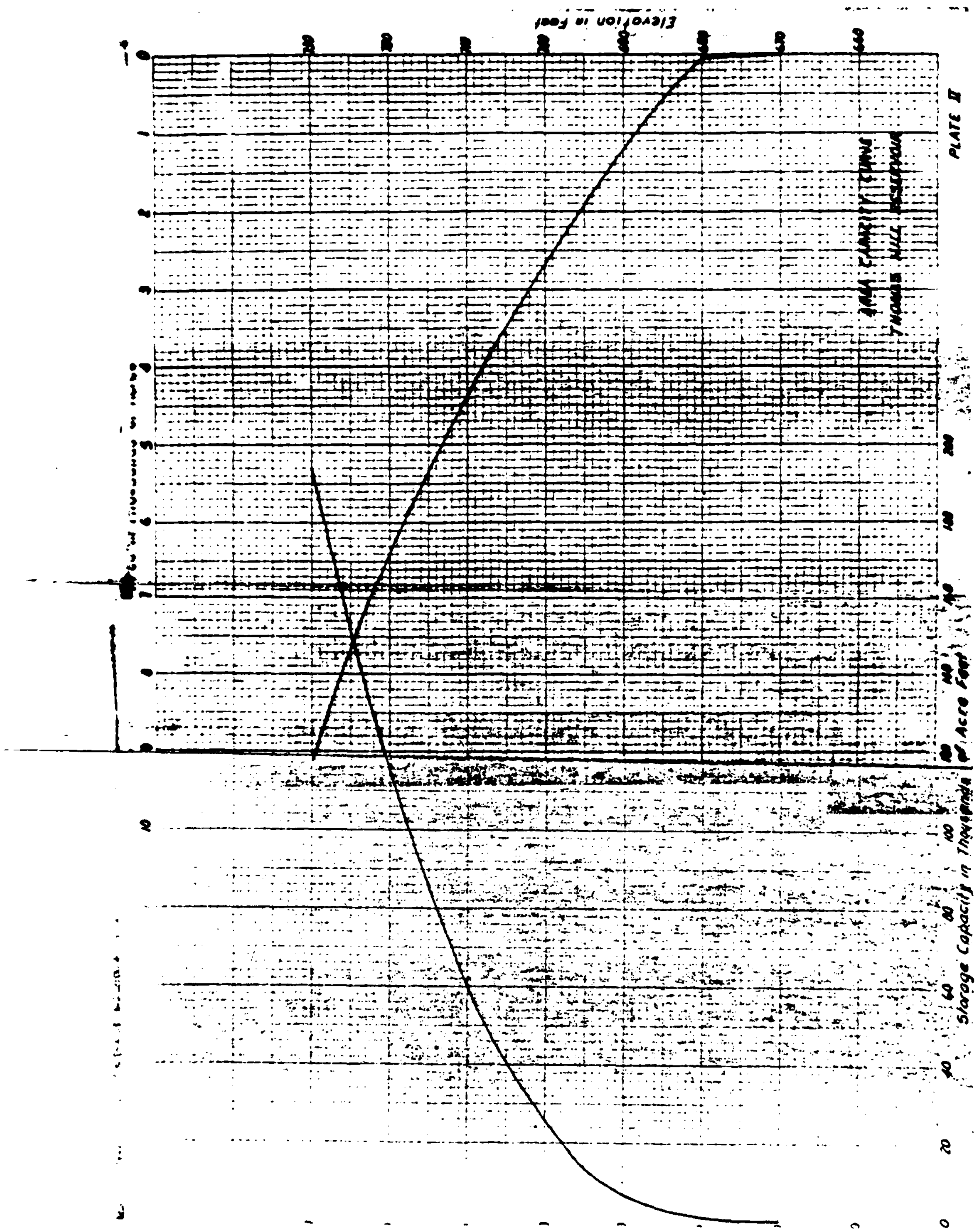

UNIT HYDROGRAPH
THOMAS HILL RESERVOIR
Discharge (10³ c.f.s.)
Time (Hours)
0
1
2
3
4
5
20
40
60
80
100
120

PLATE D-34


Elevation in Feet
PLATE II
Storage Capacity in Thousands of Acre Feet

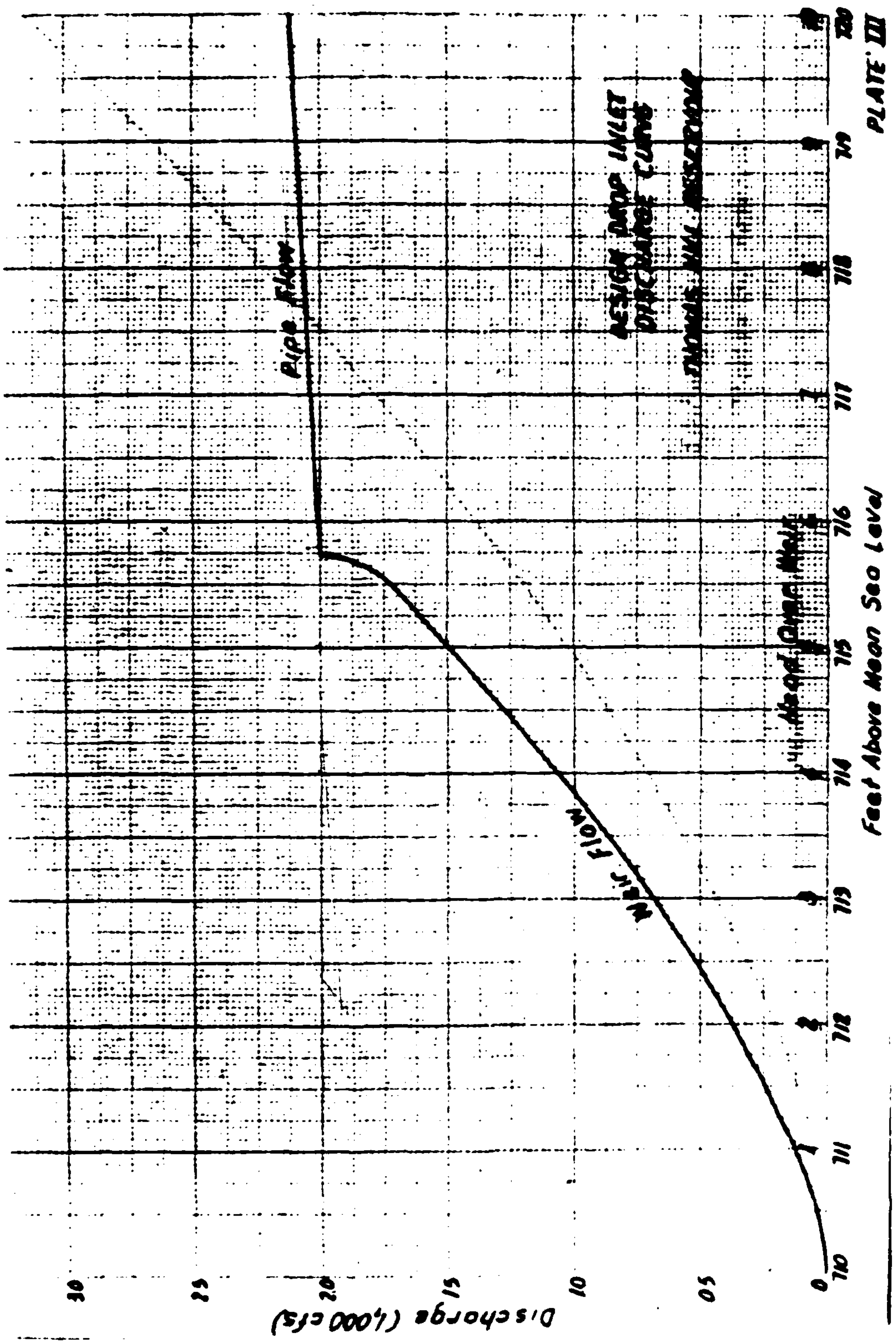
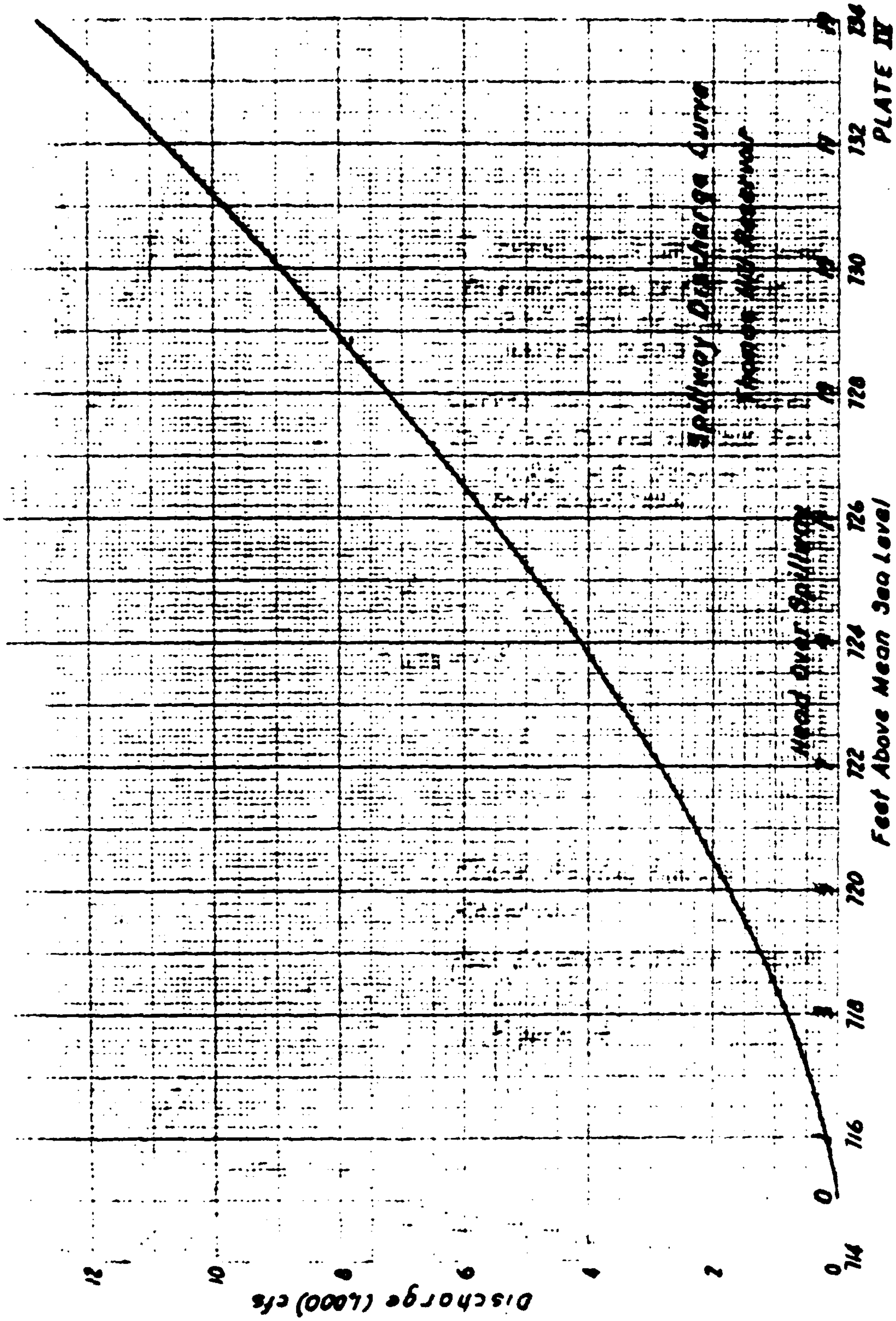
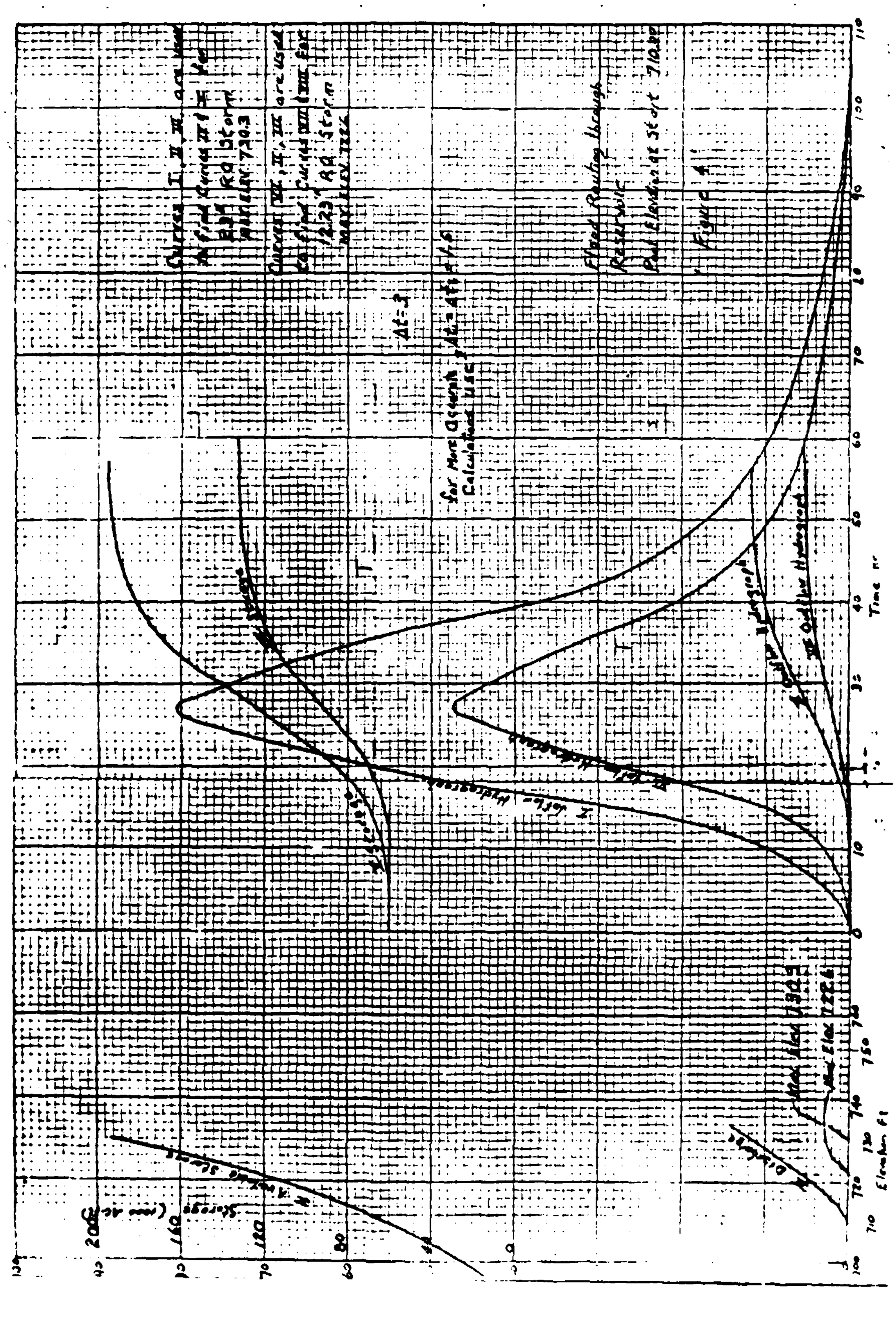
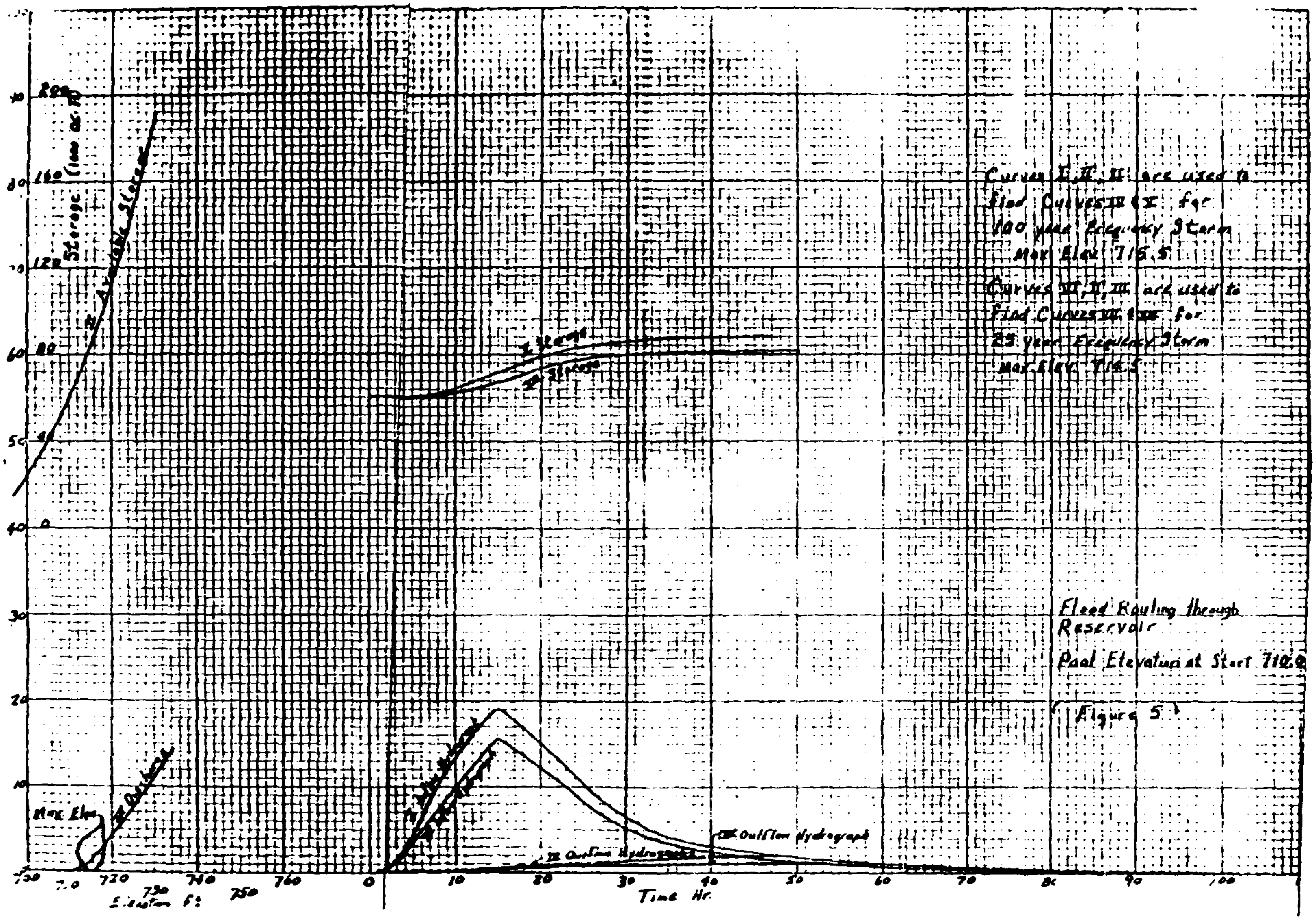
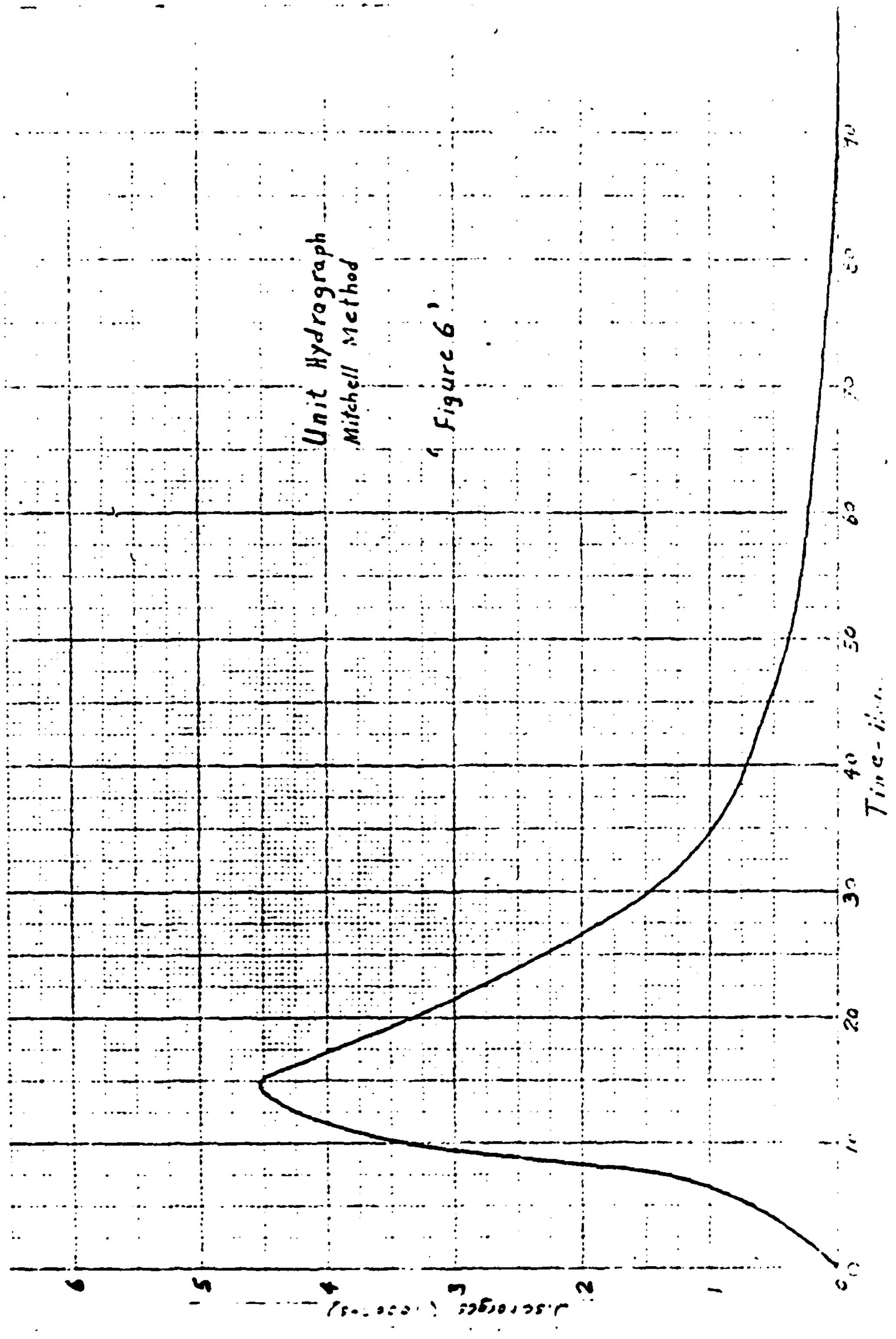


PLATE III
DESIGN DROP INLET
DISCHARGE CURVE
Pipe Flow
Weir Flow
Head Over Wall
Feet Above Mean Sea Level
Discharge (1,000 cfs)
0
05
10
15
20
25
30
710
711
712
713
714
715
716
717
718
719
720


Spillway Discharge Curve
Head Over Spillway
Feet Above Mean Sea Level
Discharge (1,000) cfs
PLATE III


Flood Routing through
Reservoir
Pool Elevation at Start 710.00
Figure 4
Δt=3
Time hr
Elevation ft


Curves I, II, III are used to
Find Curves IV & V for
100 year Frequency Storm
Max Elev 716.5
Curves VI, II, III are used to
Find Curves VII & VIII for
25 year Frequency Storm
Max Elev 714.5
Flood Routing through
Reservoir
Pool Elevation at Start 710.0
Figure 5
Storage (1000 ac. ft)
Time Hr.
Elevation Ft
Max Elev
Outflow Hydrograph


Unit Hydrograph
Mitchell Method
Figure 6

APPENDIX E
GEOTECHNICAL SAFETY EVALUATION
BURNS AND MCDONNELL
1978

Geotechnical Safety Evaluation

of

Thomas Hill Dam

for

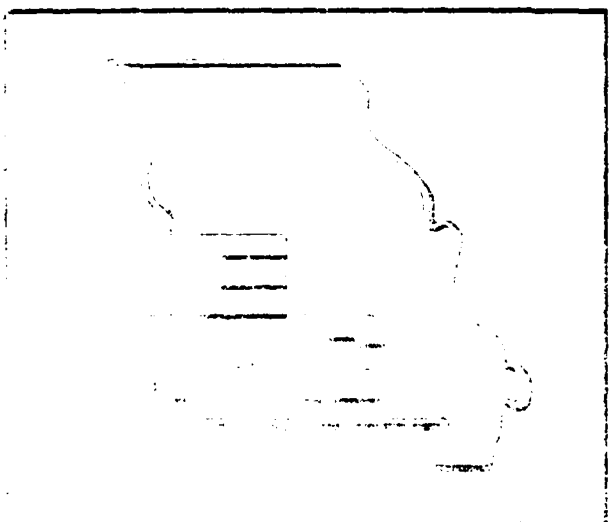
Associated Electric Cooperative

Missouri 73 Associated

Springfield, Missouri

1978

76-017-3-005



Burns & McDonnell
Engineers – Architects – Consultants
KANSAS CITY, MISSOURI

Geotechnical Safety Evaluation

of

Thomas Hill Dam

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Burns & McDonnell
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KANSAS CITY, MISSOURI

TABLE OF CONTENTS

Geotechnical Engineering
Inspection of Thomas Hill Dam

INTRODUCTION:

Increased dependence on water from the Thomas Hill Reservoir due to the construction of a third generating unit and a recognized need to assure the public of the safety of this dam has prompted Associated Electric Cooperative to request this investigation. Thomas Hill Dam has never been completely or systematically investigated since its completion in 1966. Engineer Circular 110-22-136 of the U.S. Army Corps of Engineers, which was drafted in compliance with "The National Dam Inspection Act" (PL 92-367), was used as a guide for the various phases of this investigation. Phase I (A) consisted of a review of design notes, subsurface investigation reports, laboratory test results, analyses, specifications, plans and construction correspondence. Phase I (B) consisted of a field inspection of the slope areas, outlet works, relief wells, and the emergency spillway. Phase II (A) consisted of a limited field survey to check alignment and elevations of the dam. Phase II (B) consisted of a limited boring program, installation of piezometers, check laboratory tests and an evaluation of the embankment.

The Thomas Hill Dam is located on the Middle Fork of the Chariton River. It was constructed by the Associated Electric Cooperative to supply cooling water for their Thomas Hill Power Plant. Burns and McDonnell Engineering Company was the designer of the dam and the general contractor was the Martin K. Eby Construction Company. Construction of the dam began early in 1965 and it was completed late in 1966.

Thomas Hill Dam is a homogeneous earth fill embankment with a sand blanket filter under the downstream slope. It has a maximum height of approximately 60 feet, a length of about 3000 feet and a volume of nearly 650,000 cubic yards. The outlet works consists of an uncontrolled drop inlet with a thirty-six inch diameter gate and an eight inch diameter opening for steady flow, a nine-foot diameter concrete-lined tunnel, and a hydraulic jump stilling basin. A channel type emergency spillway with a concrete control section and partial riprap lining was constructed in a cut section in the west abutment.

The purpose of this report is to present the results of an investigation of this dam following the Corps of Engineers guidelines for the safety of dams in accordance with the National Dam Inspection Act, Public Law 92-367. The scope of this report is confined to the Geotechnical Engineering aspects of the embankment and related parts of the dam. Hydraulic and hydrologic studies of the dam will be presented in a separate report.

SITE INFORMATION:

This dam is located on the Middle Fork of the Chariton River approximately eight miles north of Moberly, Missouri and three miles west of State Route C. More specifically, the dam is located in Section 24, Township 55 North and Range 16 West in Randolph County, Missouri. Figure 1 shows the location of this dam and reservoir with respect to both natural and political boundaries. Figure 2 shows the location of this dam with respect to the existing topography and the power plant grid system. It will be noted that the spillway is located on the right abutment, while the outlet works tunnel is in the left abutment. Essential dimensions are given in the following table.

Table 1 - Elevations and Dimensions of Thomas Hill Dam

Elevations:	
Top of Dam	737.0 ft.
Maximum Pool	732.0 ft.
Spillway Crest (full pool)	715.0 ft.
Normal Operation Pool	710.0 ft.
Height:	
Maximum above river bed	70 ft.
Maximum above prepared base	57 ft.
Dimensions:	
Crest length, maximum	3000 ft.
Crest width	50 ft.
Base width, maximum	600 ft.
Slope, maximum	2.5 (H) to 1.0 (V)

A general cross section of this dam is shown in Figure 3. Essential features are the cofferdam, the impervious core, cutoff, upstream and downstream berms, the sand blanket, relief wells and riprap. A profile of this dam along the centerline is shown in Figure 4; the essential features of this are the spillway, outlet tunnel, grout curtain and approximate rock surface.

Geologically, this dam is located in an area consisting of a dissected Pleistocene till plain overlying Pennsylvanian Age bedrock. Post glacial erosion by the Middle Fork of the Chariton River has cut through the till exposing bedrock on the valley walls while depositing alluvial material in the valley. The abutments are underlain by clay tills, which generally range in thickness from a few feet up to approximately ten feet. The valley section of this dam is underlain by alluvial clay, silt, sand and gravel deposits which have a total maximum thickness of about 45 feet. Both the glacial and alluvial deposits are underlain by cyclic deposits of shale, limestone, siltstone and conglomerate of the Marmaton and Cherokee Groups of the Desmoinesian Series of the Pennsylvanian System. This region is on the southwest flank of a broad, shallow syncline which plunges to the northwest and produces a low regional dip to the northwest. Superimposed upon this syncline are many smaller flexures which usually trend to either the northwest or northeast. Thinning and thickening of the Pennsylvanian cyclic deposits due to numerous minor folds and troughs yields a complex section. In addition, minor faults and joints associated with the local folding increase the complexity of the local geology.

PHASE 1 (A): REVIEW OF DESIGN AND CONSTRUCTION

Design Subsurface Investigation:

Over one hundred borings were made to investigate the dam foundations, spillway section and borrow areas during the spring of 1964. Boring locations are shown on Figure 5. It will be noted that borings along the dam center line were made at regular one hundred foot intervals, while a two hundred foot interval was used in other areas downstream of the centerline.

Approximately sixty packer type permeability tests were conducted in borings along the centerline of the dam. Measured values of permeabilities varied from 0.001 ft./day to 11 ft./day.

Samples, both undisturbed and disturbed, were taken during the field investigation and subsequently subjected to laboratory tests. Classification tests, grain size analyses and consistency limits were performed on over forty samples selected from those taken during the field investigation. Soils encountered in the abutments and upper valley areas were generally CH and CL types of materials, while SC, SM, SP, GM, GC and GP materials were found in the valley floor. Consolidation tests, permeability tests, and Q, R and S types of shear tests were performed on dam foundation material as well as compacted borrow material.

Design Analyses:

Stability analyses were made for end of construction, sudden draw-down, partial pool and steady seepage cases. Soil parameters used for the analyses and the results of these analyses are given in the following tables:

Table 2 - Soil Parameters Used for Design Analyses

I Unit Weights:

	Saturated	Submerged
A. Embankment	132.0 PCF	69.5 PCF
B. Foundation		
Impervious	124.0 PCF	61.5 PCF
Pervious	127.0 PCF	64.5 PCF

II Shear Strengths:

A. End of Construction

1. Ordinary method of slices - Case I
   Embankment: C = 2000 PSF, TAN Ø = 0
   Foundation, Impervious: C = 500, PSF TAN Ø = 0
   Foudation, Pervious: C = 0, TAN Ø = 0.5
2. Ordinary method of slices - Case II
   Embankment: C = 2000 PSF
   Foundation, Impervious: CH, C = 750 PSF, TAN Ø = 0
   CL, C = 500 PSF, TAN Ø = 0
   Foundation, Pervious: C = 0 TAN Ø = 0.5
3. Wedge method
   Embankment: C = 2000 PSF

Foundation 5' below grade: C = 750 PSF on slope and on horizontal failure plane C = 500 PSF

B. Sudden drawdown

1. Ordinary method of slices

Embankment and foundations: C = 500 PSF and TAN Ø = 0.213

C. Partial Pool

1. Ordinary method of slices

Embankment and foundations: C = 500 PSF and TAN Ø = 0.213

D. Steady Seepage

1. Ordinary method of slices

Embankment and foundations: C = 0 and TAN Ø = 0.487

Table 3 - Results of Stability Analyses

<u>Reported Factors of Safety</u>

A.	End of Construction	
	1. Ordinary method of slices - Case I	Fs = 1.29
	2. Ordinary method of slices - Case II	Fs = 1.35
	3. Wedge method	Fs = 1.40
B.	Sudden Drawdown	
	1. Ordinary method of slices	Fs = 1.30 (1.2*)
C.	Partial Pool	
	1. Ordinary method of slices	Fs = 1.5 (1.5*)
D.	Steady Seepage	

*Corps of Engineers recommended minimum factors of safety.

Total settlements in the range of two to three feet were predicted on the basis of conventional elastic and consolidation analyses.

Seepage was analyzed and a control system consisting of a cutoff trench, grout curtain, pervious drainage blanket and relief wells was selected. A cutoff trench into the rock was chosen for the abutment areas, but a partial cutoff was chosen for the valley section.

Borrow areas for impervious embankment material were selected in the glacial till areas near the dam. River sand was chosen for the drainage blanket.

Construction Records:

Records of the grout curtain constructed by the P. S. Judy Drilling Company indicate very little grout take in the shale and coal formations An average of 1.4 bags of cement was used per foot of limestone drilled. Three hundred and thirteen holes were drilled and 5085 bags of cement were used in the grouting program.

Records of compaction control were kept but not summarized. An examination of these records indicate that a vast majority of the densities were between 95 and 100 percent of the maximum dry density of the Standard Proctor test, with field moisture contents in the range of 0 to 3 percent over the optimum moisture content of this test.

A seep area appeared about half way up the intersection of the back slope and the east abutment late in 1966, shortly after the impoundment began. A flow of about 5 to 10 gpm was noted and this was monitored as the reservoir level rose. This flow remained essentially constant for several months. Pumping for the relief wells in April 1967 gave flows of 7.5, 10 and 10 gpm for relief wells 1, 2 and 3, repectively.

PHASE 1 (B): FIELD INSPECTION

A visual inspection of the embankment and adjacent areas of the dam was made on June 28 and 29, 1977.

Embankment: The water level at the time of inspection was down at least 10 feet below normal pool elevation, which permitted inspection of the riprap below the normal wave action levels. The riprap surface was level, showing no evidence of either erosion or displacement. A few scattered pieces of riprap have been badly fractured due to selective weathering. No cracks, either parallel or perpendicular to the crest, could be detected.

The crest shows no evidence of either area or local settlement, and neither transverse nor longitudinal cracks could be detected.

Piezometers installed in the embankment during the construction period were inspected and found to be dry.

The downstream slope exhibits neither arc-shaped, longitudinal or transverse cracks. Furthermore, bulges and troughs, which would indicate differential movement or slope stability problems, were absent. Erosion damage, however, was found at a number of locations along the slope. Incised gullies as deep as three feet are to be found in close intervals running down the slope and on the downstream berm. Small trees and shrubs have grown on the downstream slope.

Abutments: Seepage is evident on both abutments along the boundary with the embankement. Wet conditions have existed in these areas permanently, since cat tails and swamp grasses are growing in these areas. The amounts of seepage found at these locations appear to be small, less than five gpm. The water is clear and there is no accumulation of fines, which would have indicated piping, below the seeps. The accumulation of water in the ditches between the embankment and the abutments is not in excess of 10 gpm near the toe.

Emergency Spillway: A visual inspection of the walls, control section and floor of the emergency spillway revealed conditions that were identical to those described in the design and construction reports, which were reviewed prior to the inspection. The Pawnee Limestone, to be found in the spillway walls, has undergone little or no alternation by weathering since its exposure. Joints that were opened by blasting are still evident but show no movement. The reinforced concrete control section is uncracked and appears to be sound. Since the spillway has never been activated, there is no evidence of erosion within the section. Small trees and scrub growth have been allowed to grow in the spillway, especially in the area south of the control section. Over-excavated areas in the spillway floor have ponded water and cattails are growing in them. Some of the limestone blocks used as riprap have weathered badly and have shattered.

<u>Outlet Works and Stilling Basin</u>: With the gates of the intake structure closed, the outlet tunnel and stilling basin were pumped empty for inspection on July 29, 1977. The intake structure shows no signs of distress and only a minor amount of scour of the concrete at the invert is evident. Minor leaks, less than 1 gpm, were found along joints in the tunnel and many of these joints have carbonate deposits around them. No evidence of structural distress, such as longitudinal cracks or cracks between joints, could be found in the tunnel lining. The stilling basin has experienced some minor damage to one of its dissipaters, otherwise it appears to be in excellent condition.

<u>Downstream Area</u>: This area was ponded with water one to two feet above the relief well drains at the time of the first inspection. Scrub growth, small willow trees, swamp grasses and cattails were growing over the area. Bottom ash, probably from the stock piles immediately adjacent to the downstream area, and material eroded from the slopes had accumulated in this area. Evidence of small animals, beaver or muskrat, was in the area. This area was cleared demucked and drained during the last week of October 1977.

<u>Relief Wells</u>: The relief wells could not be inspected on either June 29th or July 29th of 1977, since the water levels could not be measured until the downstream area had been demucked. Water levels were first measured on November 16, 1977 and are reported in the following table. Crimps were reported in the relief well tees at this time, but flows of from 5 to 10 gpm were observed.

Table 4 - Relief Well Measurements

Well No.	Depth of Well* Ft.	Depth to Water* Ft.	
1	50.2	10.5+	11.1++
2	50.5	11.2	11.2
3	50.6	10.4	11.0

* From top of well casing
\+ November 16, 1977
++ March 15, 1978

Due to adverse weather conditions and problems with equipment availability, the relief wells were not inspected and tested until the 15th and 16th of March, 1978. Each well was measured, inspected for corrosion and damage, and pump tested. A small submersible pump was placed near the bottom of a well and the well was pumped at a rate of 14.5 to 15.0 gallons per minute for approximately two and one half hours. Drawdowns of three, four and five feet occurred in relief wells 1, 2 and 3, respectively, within two minutes. Adjacent wells were observed during the pumping period, but no observable changes in water levels took place. Water from the wells was collected to observe turbidity, but the water was very clear. Checks were made of the quantity of flow during the pumping period. After the pump was shut off, the water levels returned to their original position within one minute. From these observations it may be concluded that the relief wells are in good condition.

Phase II (A): Alignment and Elevation Survey

The centerline of the roadway, which is 12.5 ft. upstream from the centerline of the dam, was checked for alignment and elevation in May, 1977. In addition, the elevations of the dam were measured on 10 ft. intervals at three cross sections, stations 28+00, 30+00 and 32+00. Except for some erosion rivlets in the slopes, the slopes exhibited no undulations and retained their original dimensions. Little or no settlement was evident.

Phase II (B): Additional Investigations of the Embankment

On July 20-25, 1977, three borings, D-197, 198, and 199 were made on the embankment at station 29+00 at 30, 150 and 250 feet south of the centerline, respectively. A drill rig using a 4-inch auger was used for making all of these borings. Shelby tube samples (ASTM D1587) were taken at depth intervals of five feet in all of the borings where cohesive soils were encountered. Standard Penetration tests (ASTM D1586) were performed at depth intervals of five feet where sands, in the blanket, were encountered. Three (3) boring logs describing the materials encountered, their depths and thickness, and sampling locations are given in the Appendix.

Piezometers, of the open tube type, were set at depths of 50 and 82 feet in Boring D-197, and at depths of 11 and 9 feet in Borings D-198 and 199,

respectively. The open tube piezometers, Casagrande type, consisted of a porous tube, 1½ inch outside diameter by 24 inches long and connected to ½ inch outside diameter polyethlene plastic tubing. Ottawa sand was used to encapsulate the porous tube in the boring and two feet of bentonite was used to seal the borehole above the sand backfill.

Thirty-one Shelby tube samples were visually inspected and representative specimens were selected for testing. Classification tests, including grain size analyses (ASTM D422) and consistency limits (ASTM D423 and 424), were performed on four samples. The results of these tests are given in the Appendix and are summarized in the following table.

Table 5 Classification Test Results

Boring No.	Depth, Feet	Liquid Limit %	Plastic Limit %	Pass #200	Unified Classification
D197	13'-15'	40	16	71.2	CL
D197	68'-70'	27	16	61.9	CL
D198	8'-10'	41	17	72.9	CL
D199	8'-10'	36	14	69.7	CL

Six unconfined compression tests (ASTM D2166) were performed to ascertain strength variations, and these results are shown in detail in the Appendix and are summarized in Table 3.

Table 6 Unconfined Compression Test Results

Boring No.	Depth, Feet	Dry Density PCF	Moisture Cotent %	Unconfined Strength PSF	Axial Strain At Failure
D197	3'-5'	116	15.2	8100	6
D197	8'-10'	118	16.3	7200	11
D197	28'-30'	116	15.3	11000	3
D197	43'-45'	118	13.4	11100	2
D197	63'-65'	108	19.8	6700	5
D197	73'-75'	99	24.9	2900	6

Permeability tests were performed on three samples of embankment material and one sample from the sand blanket. Two of the samples, ST-15 and ST-3, were remolded due to sample disturbance. The results of these tests are given in Table 7.

Table 7 Laboratory Permeability Test Results

Boring No.	Sample No.	Depth, Feet	Dry Density PCF	k, Permeability Coefficient $^{cm}/sec$ x 10^{-6}
D197	ST-7	33-35	115	0.15
D197	ST-13	63-65	105	0.28
D197	ST-15	73-75	109	0.72
D198	ST-3	13-15	101	270

Consolidated-Undrained (R) triaxial tests were performed on two sets of three samples of the embankment material and one set of three samples of the foundation material. Results of these tests are given in detail in the Appedix and are summarized in Table 8.

Table 8 Consolidated-Undrained Triaxial Test Results

Boring No.	Depth, Feet	Dry Density Range PCF	Ø Degree	C TSF
D197	13-15	114-117	20.7	1.4
D197	68-70	104-106	11.3	0.5*
D198	8-10	112-114	17.6	1.0

* Questionable test results, silty clay with sand lenses.

Consolidated-Drained (S) direct shear tests were performed on three sets of three samples of the embankment material. The results of these tests are given in detail in the Appendix and are summarized in Table 9.

Table 9 Consolidated-Drained Direct Shear Test Results

Boring No.	Depth, Feet	Dry Density PCF	Ø Degree	C TSF
D197	28-30	109-116	21	0.6
D197	43-45	116-118	29	0.3
D199	13-15	108-110	26.5	0.3

It will be noted that these shearing strength exceed those used in the original design analyses using Corps of Engineers methods; therefore, there seems to be no need to undertake the expense of additional stability analyses by other methods.

SUMMARY:

Phase I (A) - A review of the complete design file indicates that a standard, conservative design procedure was used. Construction was routine, at least according to the construction records and correspondence. Less

quality control work was used than would be required now. However, the quality control work that was done indicates reasonable density and moisture control was being used. Small seeps developed in the abutments on first filling, but this is not unusual for dams founded on limestone in this area. Construction correspondence reveals that they were monitored periodically after they developed and that the quantity of seepage did not increase.

Phase I (B) - An inspection of the dam revealed a few minor problems. The downstream toe area had been allowed to silt up and pond water, and minor erosion by rainfall runoff had taken place on the downstream slope. Shortly after this was brought to the owners attention as undesirable, the area was cleared. Other than these problems, the dam appeared to be unchanged from the time of construction. The relief wells were tested and found to be in good condition.

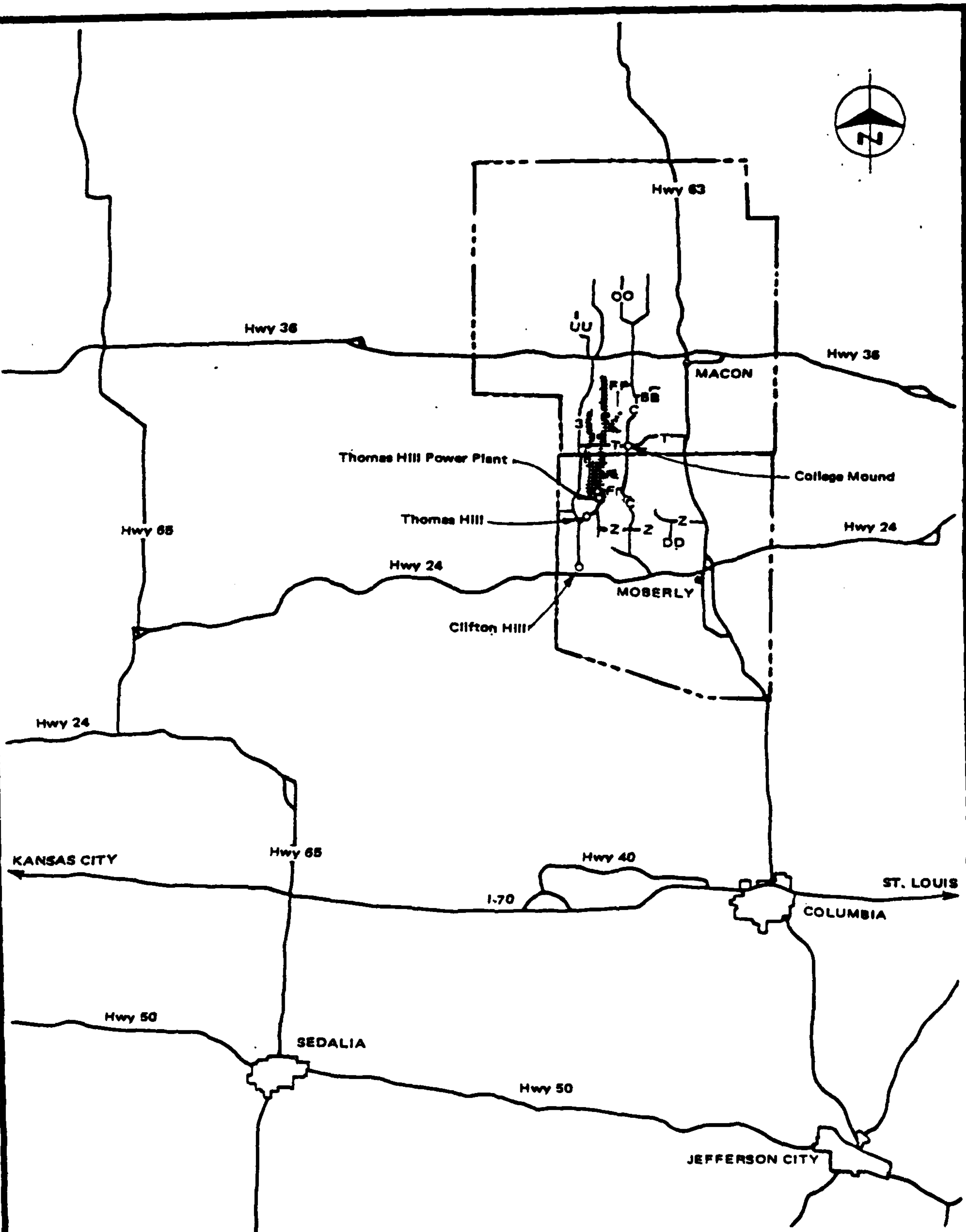
Phase II (A) - A check of the alignment and elevations of the centerline and at three cross sections revealed that the dam had undergone virtually no settlement or distortion.

Phase II (B) - A limited boring and testing program indicates that the materials used in the embankment and filter agree with the descriptions given in the design and construction records. Shear strengths exceed those assumed in the original stability analyses. Piezometers were installed in the boreholes for future monitoring of the dam.

CONCLUSION:

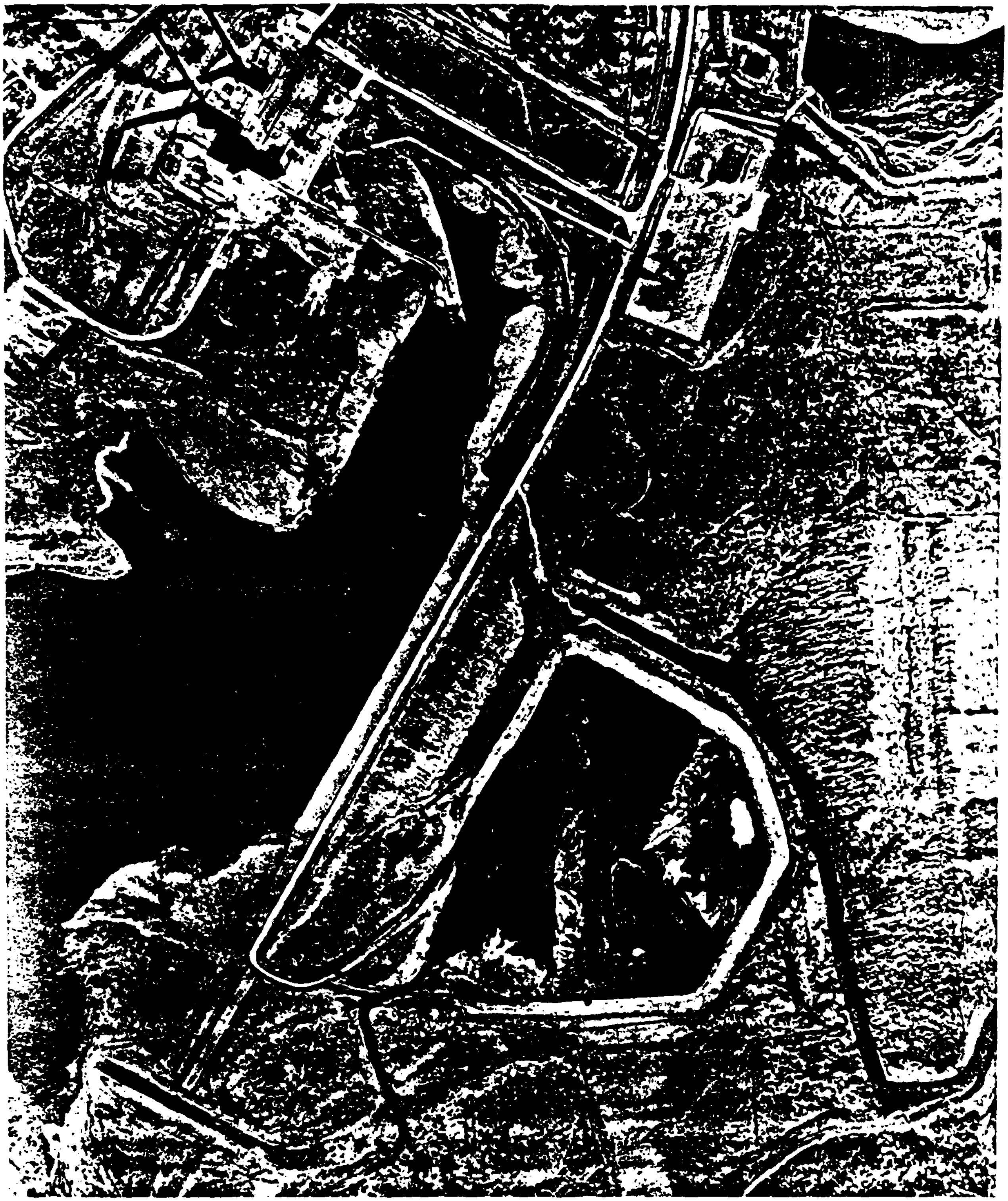
This dam meets the safety requirements as set forth in Engineer Circular 110-22-136 of the U.S. Army Corps of Engineers. However, an annual maintenance program should be instituted by the owner to insure future use and safety of this dam. In particular, the downstream should be kept clear of sediment and scrub growth, the erosion features on the downstream slope should be filled and seeded, and the entire area should be kept cleared of scrub growth and routinely mowed.

FIGURES



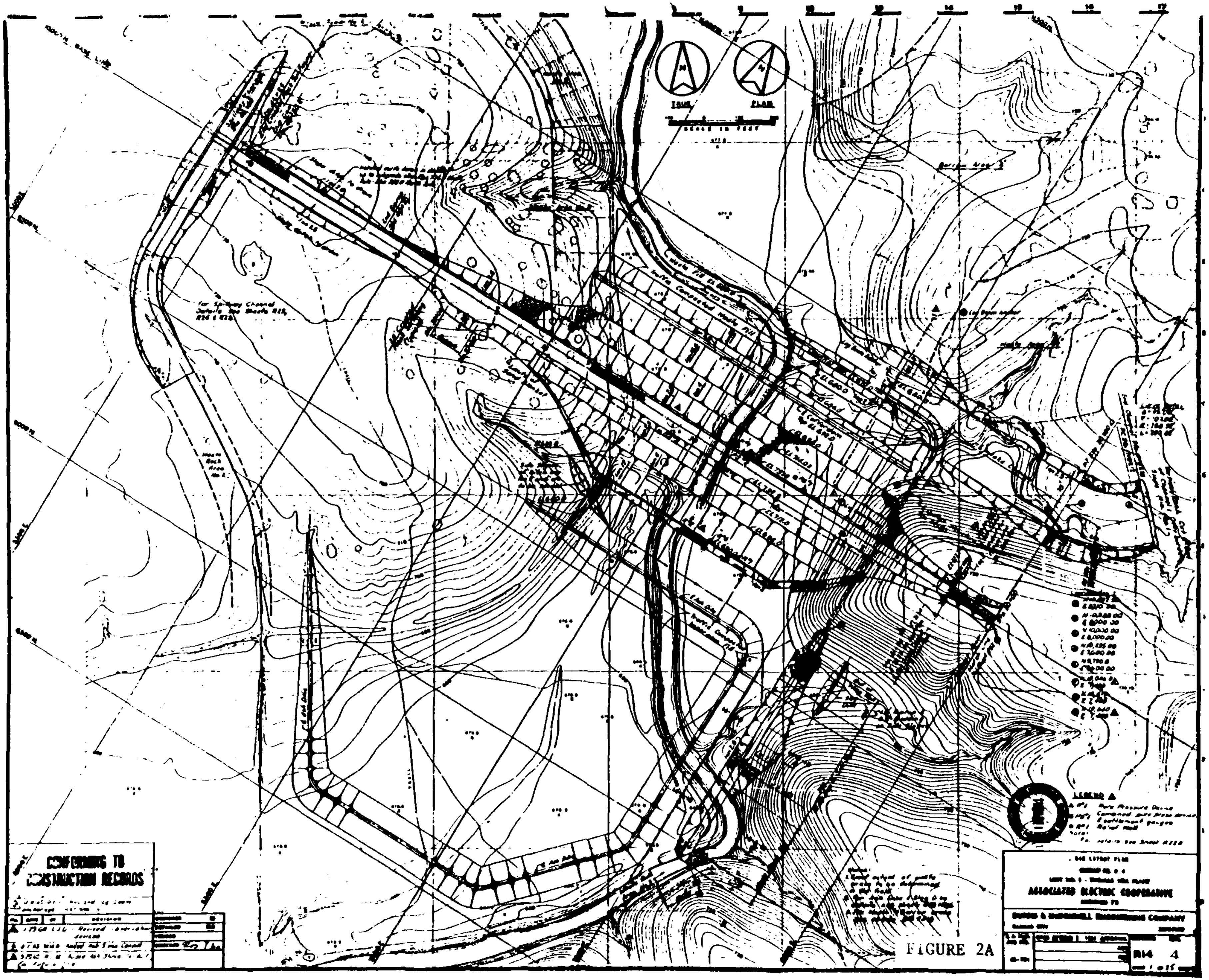
DATE	ASSOCIATED ELECTRIC COOP THOMAS HILL PLANT LOCATION SHEET	CONTRACT NO.
DESIGNED		PROJECT NO. 76-017-1
DETAILED	Burns & McDonnell Engineers – Architects – Consultants KANSAS CITY, MISSOURI	DRAWING NO. REV. 1 –
CHECKED		

M-2-3-43 092276



Barns & McDonnell
Engineers-Architects-Consultants

Figure 2
LOCATION SHEET OF
POWER PLANT AND DAM



CONFORMING TO CONSTRUCTION RECORDS
ASSOCIATED ELECTRIC COOPERATIVE
TRUE
PLAN
SCALE IN FEET
LEGEND
For Spillway Channel Details See Sheets R23, R24 & R25
R14 4

FIGURE 2A

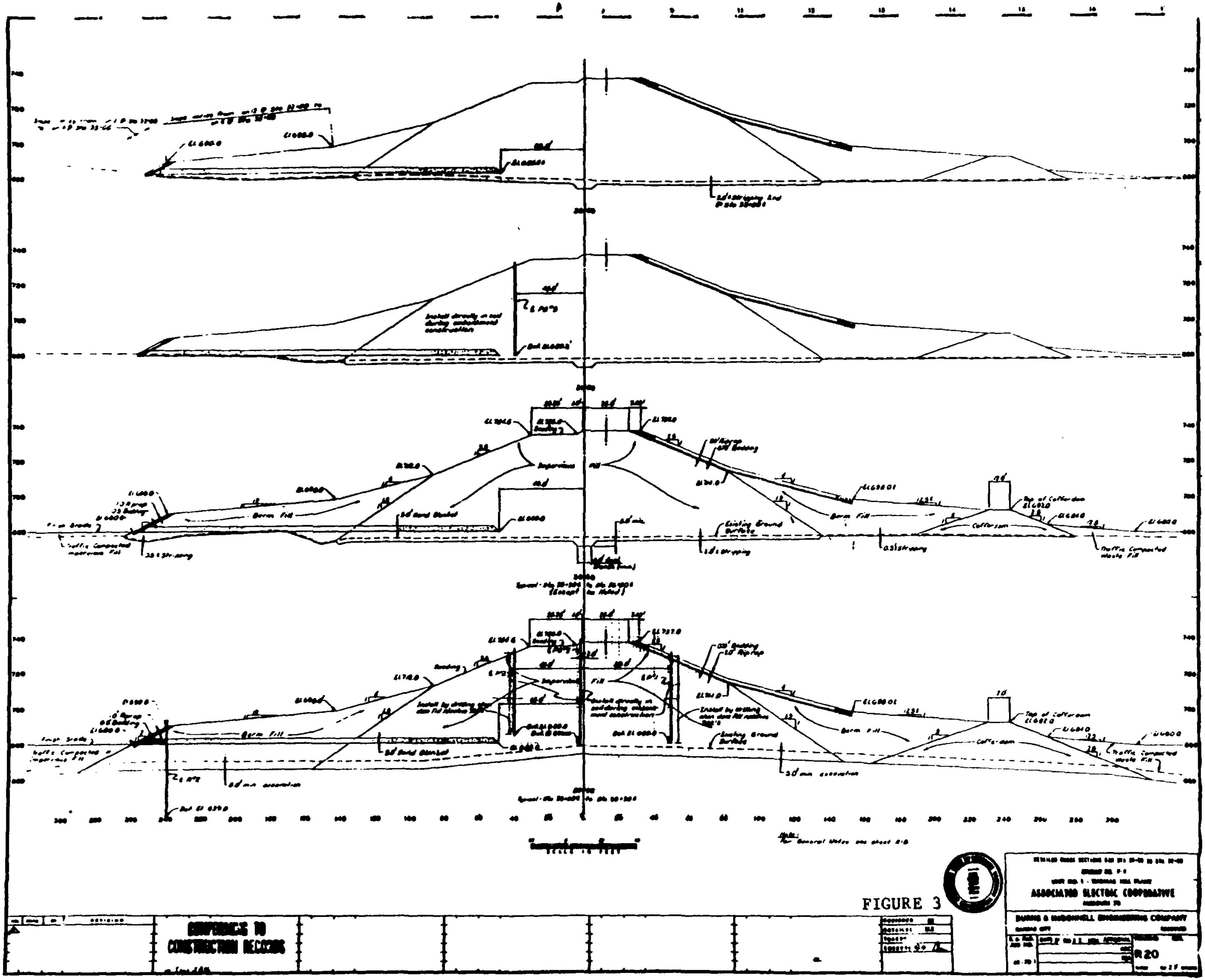

Berm Fill
Impervious Fill
Cofferdam
Top of Cofferdam
Existing Ground Surface
Traffic Compacted Waste Fill
ASSOCIATED ELECTRIC COOPERATIVE
R20

FIGURE 3

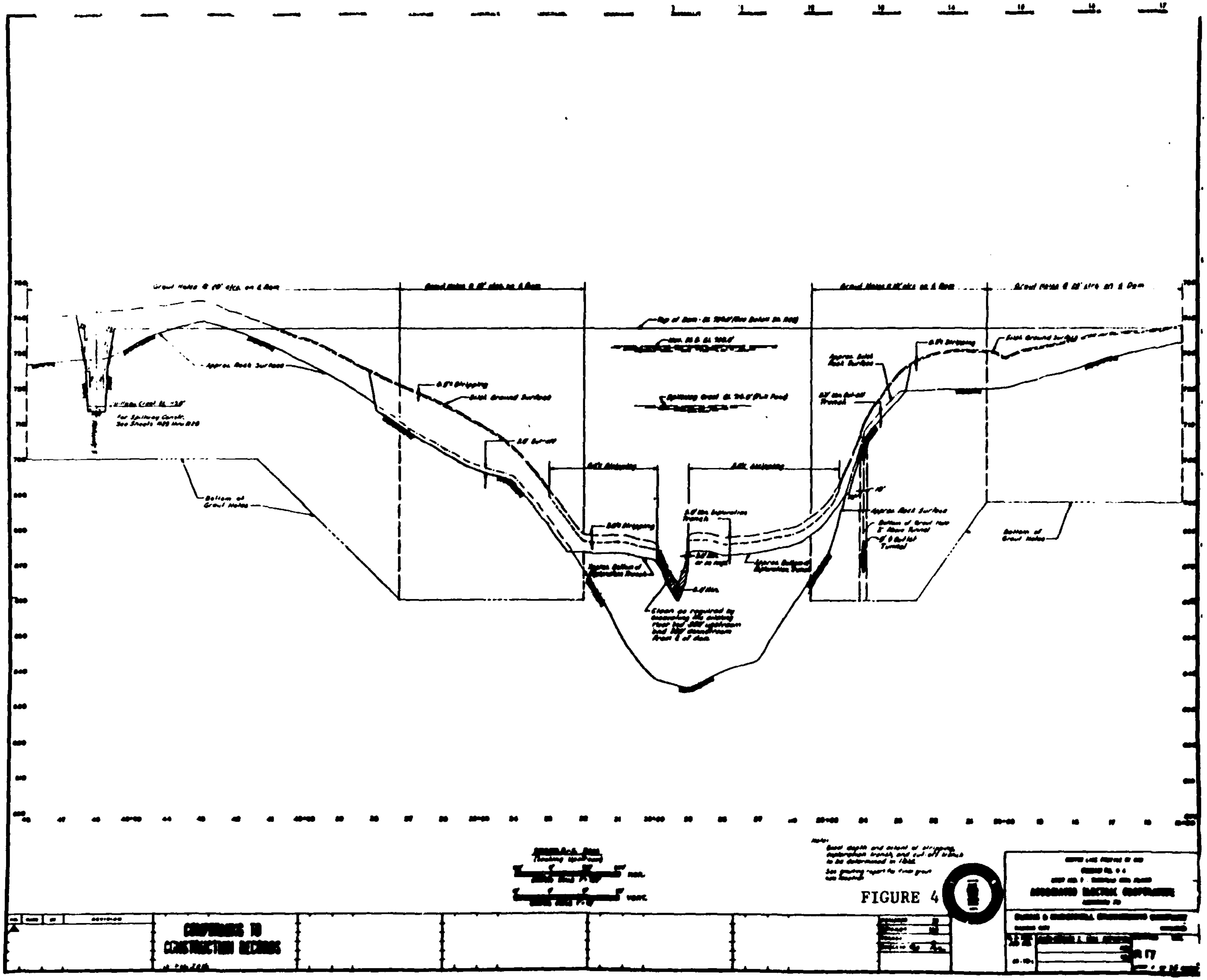

Bottom of Grout Holes
Approx. Rock Surface
CONFORMING TO CONSTRUCTION RECORDS

FIGURE 4

APPENDIX

BORING LOGS

DRILLING LOG

JOB NO. 76-017-1	PROJECT Thomas Hill Dam Study		HOLE NO. D-197
GROUND ELEV. 734	LOCATION Sta 29+00 30' So. of crest		SHEET 1 OF 5

DRILLING TYPE	HOLE DEPTH	OVERBURDEN FOOTAGE	BEDROCK FOOTAGE	OVERBURDEN SAMPLES	NO. CORE BOXES	% CORE RECOVERY	WATER TABLE
4" Auger	84.5	84.5	0	17	–	–	

DRILLING CO. Raymond International	DRILLER(S) Bud Anderson
DRILLING RIG CME 75	PENETRATION TEST SPT
DRILLING DATE 7/20/77 TO 7/20/77	INSPECTOR(S) PATRICK GOEKE

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS	BOX OR SAMPLE NO.	REMARKS
1						
2						
3–5	Tanish Brown clay with fine gravel. gravel sizes range from 1/16" to 1/2". Some silt in the clay. damp, medium plastic very stiff	CL		18" ~~24"~~	ST 1	slight crimp in bottom of tube
6						
7						
8–10	Tanish brown silty clay, some course sand and fine gravel mixed in. Damp, very stiff medium plasticity	CL		24"	ST 2	
11						
12						
13–14	Tanish brown with some gray silty clay with some fine sand mixed in, stiff			24"	ST 3	One crimp in bottom of tube

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DRILLING LOG

PROJECT: Thomas Hill Dam Study   HOLE NO. D-197   SHEET 2 OF 5

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS		BOX OR SAMPLE NO.	REMARKS
15	but softer than previous samples damp to moist, plastic, trace of fine gravel	CL		24"		ST 3	
16							
17							
18–20	Tanish brown silty clay with fine sand and small amounts of fine gravel. Damp, less plastic than before, about same stiffness Less moist	CL		24		ST 4	no crimps in tube
21							
22							
23–25	similar to sample 3 Tanish brown silty clay with ~~some~~ trace sand and trace fine gravel Damp to moist, stiff medium plasticity	CL		24"		ST 5	no crimps in tube
26							
27							
28–30	Brown clay with some silt lesser amounts of sand & gravel Stiff to very stiff, Damp. medium plasticity	CL				ST 6	didnt crimp the bottom of tube, but bent the bolt holes
31							

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DRILLING LOG

PROJECT Thomas Hill Dam Study HOLE NO. D-197 SHEET 3 OF 5

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS		BOX OR SAMPLE NO.	REMARKS
33–35	Brown Silty Clay with some sand and fine gravel, damp, very stiff, medium plasticity.	CL		24		ST 7	no crimps
38–40	Brown Silty Clay with some Sand and fine gravel, damp, V. stiff to hard, medium to low plasticity	CL		24"		ST 8	no crimps
43–45	Brown clay, very silty, with a trace of sand, some fine gravel, v stiff to hard, damp medium plasticity	CL		24"		ST 9	no crimps
48–50	Tanish brown sandy clay, damp, stiff, medium plasticity	CL-SC		22		ST 10	bottom of tube is crimped

Depth scale: 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50

DRILLING LOG

PROJECT: Thomas Hill Dam Study   HOLE NO. D-197   SHEET 4 OF 5

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS		BOX OR SAMPLE NO.	REMARKS
51							
52							
53–55	Brown Silty Clay with some gravel, damp, very stiff, Low plasticity	CL		18"		ST 11	
56							
57							— approximately the end of fill
58–60	Brown and gray sandy silty clay, damp to moist, very stiff, medium plasticity (till)	CL		13"		ST 12	Tube refused after 13" of push. Crimped bottom
61							
62							
63–65	Gray clay with some silt and sand (till). Damp to moist, stiff, medium to low plasticity	CL		21"		ST 13	No crimps
66							
67							
68							

BURNS & McDONNELL ENGINEERING COMPANY

DRILLING LOG

PROJECT: Thomas Hill Dam Study HOLE NO. D-197 SHEET 5 OF 5

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS		BOX OR SAMPLE NO.	REMARKS
69–70	Gray & Brown Sandy silty clay Moist to wet, medium stiff Medium to high plasticity	SC		22"		ST 14	WET SAMPLE
70–73							wood pieces coming up in wash water
73–75	Top. Gray clay, very plastic, moist. Bottom Gray fine to med. sand, very dirty but non-plastic.	CL-CH / SP		24"		ST 15	
75–78							
78–80	Gray sand coming up in the cuttings	SP				ST 16	No recovery
80–84							Set 24' porous stone piezometer at 82'
84–86	Gray fine to medium sand very dense, clean, poorly graded, no gravel total depth 84.5	SP	21/40/41			SS 17	83 … 84.5

DRILLING LOG

JOB NO. 76-917-1	PROJECT Assoc. - Thomas Hill Unit #3					HOLE NO. 2-198	
GROUND ELEV. 697°	LOCATION Sta 29+00 North edge of berm					SHEET 1 OF 3	
DRILLING TYPE	HOLE DEPTH	OVERBURDEN FOOTAGE	BEDROCK FOOTAGE	OVERBURDEN SAMPLES	NO. CORE BOXES	% CORE RECOVERY	WATER TABLE
4" Auger	40'	40'	0	8	-	-	—
DRILLING CO. Raymond International				DRILLER(S) Bud Anderson			
DRILLING RIG CME 75				PENETRATION TEST SPT			
DRILLING DATE 7/21/77 TO 7/21/77				INSPECTOR(S) PATRICK GOEKE			

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS	BOX OR SAMPLE NO.	REMARKS
1						
2						
3 – 5	Brown Silty Clay with traces of fine sand and fine gravel Stiff, damp, medium plasticity	CL		24"	ST 1	No crimps on tube
6						
7						
8 – 10	Same as above with slightly more sand and slightly higher moisture content.	CL		24"	ST 2	
11						
12						
13 – 14	Top: Same as above Bottom: Brown sand, fine to med. grained clean, dry to damp			18"	ST 3	3' sand blanket encountered

BURNS & McDONNELL ENGINEERING COMPANY

DRILLING LOG

PROJECT Assoc - Thomas Hill Unit #3 HOLE NO. D-198 SHEET 2 OF 3

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS		BOX OR SAMPLE NO.	REMARKS
15	Bottom: Brown sand from drainage blanket.					ST 3	
16							
17							
18	Bit tip wet when pulled from hole						
19	Brown silty clay with trace of fine sand and fine gravel, damp to moist, plastic, stiff	CL		24"		ST 4	
20							
21							
22							
23							
24	Brown medium sand, dirty, medium dense, moist, no gravels.	SP	6/13/13	18"		SS 5	No recovery drove spoon to pick up sample
25							
26							
27							
28							
29	Grayish brown very silty clay. Moist to damp, plastic, med. stiffness	CL	4/5/6			SS 6	
30							
31							
32							

BURNS & McDONNELL ENGINEERING COMPANY

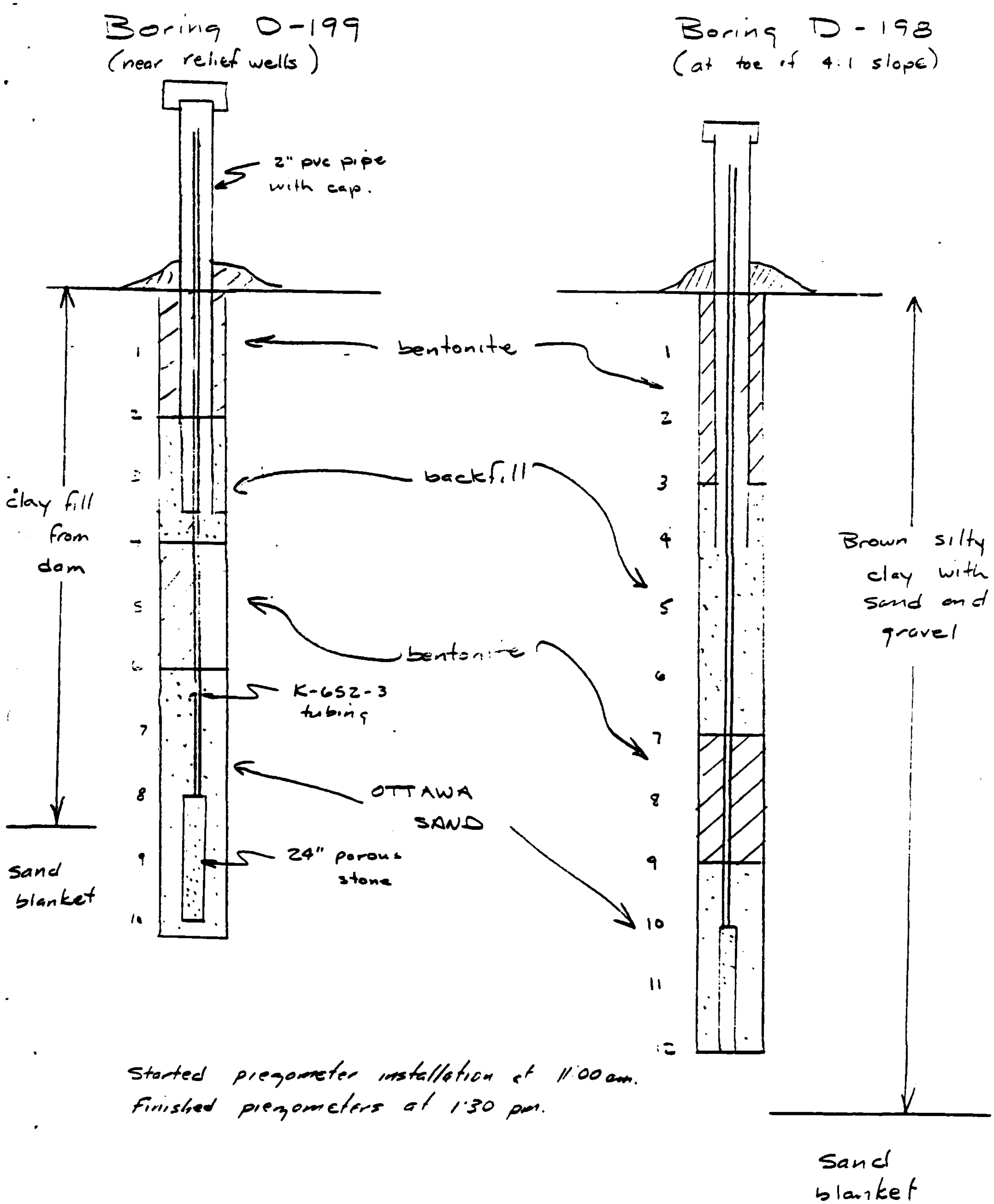
DRILLING LOG

PROJECT Assoc. - Thomas Hill Unit #3 HOLE NO. D-198 SHEET 3 OF 3

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS		BOX OR SAMPLE NO.	REMARKS
33–35	Brown clayey sand, wet, soft Low plasticity	SC		?		ST 7	
38.5–40	Gray medium sand, dirty wet, medium dense.		4/5/6	15"		SS 8	
	Total depth 40.0 FT						

Depth scale: 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50

76-017-3-005



Started piezometer installation at 11:00 am.
Finished piezometers at 1:30 pm.

DRILLING LOG

JOB NO. 76-017-3-005	PROJECT Assoc.	HOLE NO. D-199
GROUND ELEV. 690	LOCATION Sta 29 near relief well	SHEET 1 OF 1

DRILLING TYPE	HOLE DEPTH	OVERBURDEN FOOTAGE	BEDROCK FOOTAGE	OVERBURDEN SAMPLES	NO. CORE BOXES	% CORE RECOVERY	WATER TABLE
4" Auger	30'	30'	0	6	-	-	-

DRILLING CO. Raymond Intr.	DRILLER(S) Bud Anderson
DRILLING RIG CME 75	PENETRATION TEST SPT
DRILLING DATE 7/25/77 TO	INSPECTOR(S) Patrick Goeke

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS	BOX OR SAMPLE NO.	REMARKS
2						
4	Brown clay with sand, silt and fine gravel, damp, stiff.	CL		24"	ST 1	
6						
8	same in top bottom fine to med. brown sand			24"	ST 2	
10						
12						
14	brown silty sandy clay moist, plastic, med. stiff	CL-SC		24"	ST 3	
16						
18	brown very silty sandy clay moist to wet very plastic	SC		18"	ST 4	
20						
22						
24					ST 5	
26						hole begining to cave
28	Grayish blue organic sandy silty clayey gravely aluvial deposit wet.				SS-6	driven from 25 to 30

Total depth 30'

122673 Barns & McDonnell Engineers-Architects-Consultants Form J-2-1-1A

LABORACTORY TEST RESULTS

KANSAS CITY TESTING LABORATORY

SUMMARY OF SOIL TESTS

PROJECT Assoc. Elec.-- Thomas Hill PROJECT NO 76-017-3-005

BORING NUMBER	SAMPLE NUMBER	DEPTH ft	% MOISTURE	DRY UNIT WT.-PCF	UNCONFINED COMPRESSION		ATTERBERG LIMITS			% -200	UNIFIED CLASSIFICATION	SPECIFIC GRAVITY				REMARKS
					PSF	%E	LL	PL	PI							
D 197	ST 1	3.0- 5.0	15.2	115.9	8066	6.3										
	ST 2	8.0-10.0	16.3	118.0	7156	10.8										
	ST 3	13.0-15.0	15.3	116.7			40	16	24	71.2	CL	2.684				triaxial compression
	ST 4	18.0-20.0	16.6	115.1												
	ST 5	23.0-25.0	16.3	112.0												
	ST 6	28.0-30.0	15.3	115.7	11012'	3.1										'no failure / shear test
	ST 7	33.0-35.0	15.3	115.1												permeability test
	ST 8	38.0-40.0	14.8	119.8												
	ST 9	43.0-45.0	13.4	118.2	11112'	2.2										'no failure / shear test
	ST10	48.0-50.0	16.1	117.0												
	ST11	53.0-55.0														not tested
	ST12	58.0-60.0	16.1	116.1												
	ST13	63.0-65.0	19.8	108.0	6701	4.5										permeability test
	ST14	68.0-70.0	19.0	104.0			27	16	11	61.9	CL	2.699				triaxial compression
	ST15	73.0-75.0	24.9	99.4	2933	6.3										permeability test
	ST16	78.0-80.0														not tested
	ST17	83.0-84.5														not tested
D 198	ST 1	3.0- 5.0	16.4	119.1												
	ST 2	8.0-10.0	17.6	114.2			41	17	24	72.9	CL	2.736				triaxial compression
	ST 3	13.0-15.0	17.6	111.8												permeability

KANSAS CITY TESTING LABORATORY

SUMMARY OF SOIL TESTS

PROJECT Assoc. Elec.-Thomas Hill

PROJECT NO 76-017-3-005

BORING NUMBER	SAMPLE NUMBER	DEPTH ft	% MOISTURE	DRY UNIT WT.—PCF	UNCONFINED COMPRESSION		ATTERBERG LIMITS			% -200	UNIFIED CLASSIFICATION	SPECIFIC GRAVITY				REMARKS
					PSF	%E	LL	PL	PI							
D 198	ST 4	18.0-20.0	16.0	'												sand sample--disturbed
	ST 5	23.5-25.0														not tested
	ST 6	28.5-30.0														not tested
	ST 7	33.0-35.0	21.1	'												' insufficient sample
	ST 8	38.5-40.0														not tested
D 199	ST 1	3.0- 5.0														
	ST 2	8.0-10.0	19.8	107.0			36	14	22	69.7	CL	2.761				triaxial compression
	ST 3	13.0-15.0	17.9	110.0												shear
	ST 4	18.0-20.0	17.7	108.7												
	ST 5	23.0-25.0	19.6	105.4												
	ST 6	28.0-30.0														not tested

77

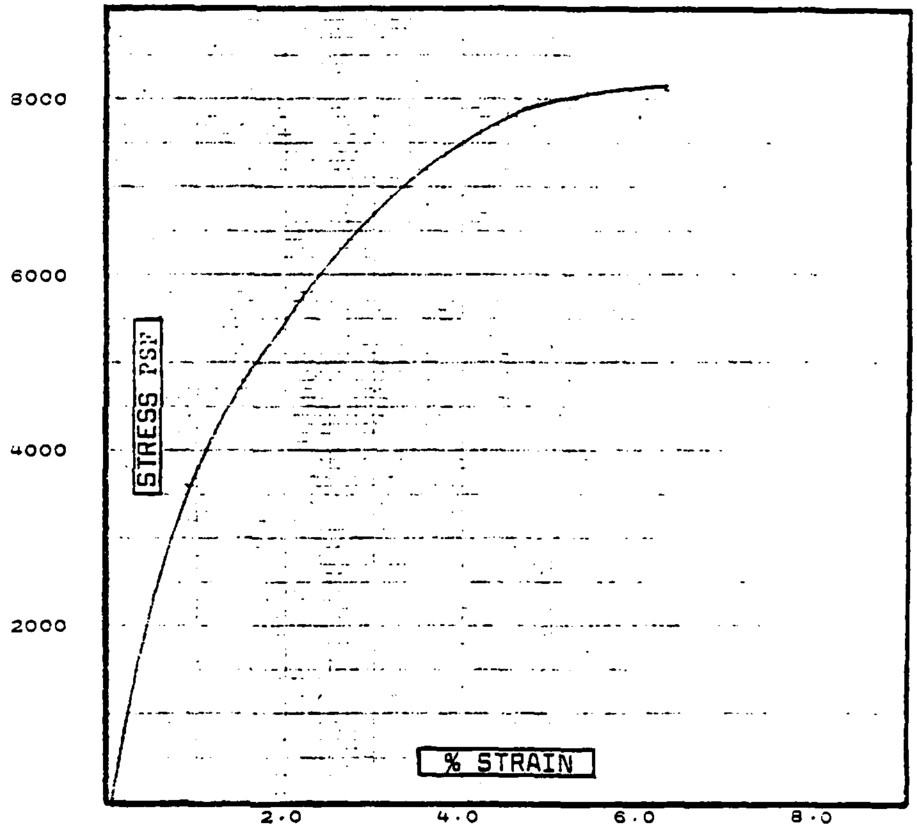
KANSAS CITY TESTING LABORATORY

76-017-3-005

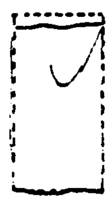
BORING NO. D 197 SAMPLE NO. DEPTH: 3.0-5.0 ft.

% STRAIN	PSF STRESS
0.9	3611
1.8	5161
2.7	6281
3.6	7071
5.4	8003
6.3	8066

UNCONFINED COMPRESSION



FAILURE SKETCH



DESCRIPTION: Brown silty clay with calcareous deposits and subangular gravel

DIAMETER: 2.85 in.

HEIGHT: 5.58 in.

MOISTURE: 15.2 percent

UNIT DRY WEIGHT: 115.9 lbs/ft^3

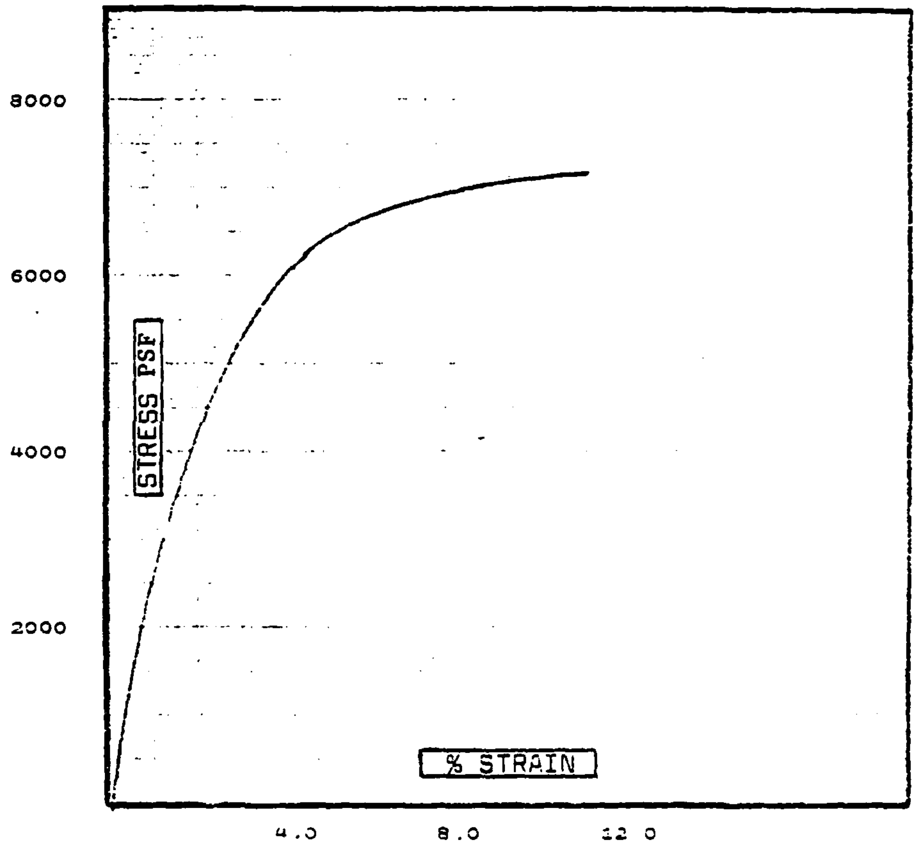
KANSAS CITY TESTING LABORATORY

76-017-3-005

BORING NO. D 197 **SAMPLE NO.** **DEPTH:** 8.0-10.0 ft.

% STRAIN	PSF STRESS
1.3	3062
2.7	5044
4.5	6257
6.3	6898
9.0	7123
10.8	7156

UNCONFINED COMPRESSION



FAILURE SKETCH

DESCRIPTION: Brown mottled gray silty clay with calcareous deposits and small rounded gravel

DIAMETER: 2.85 in.

HEIGHT: 5.58 in.

MOISTURE: 16.3 percent

UNIT DRY WEIGHT: 113.0 lbs/ft^3

KANSAS CITY TESTING LABORATORY

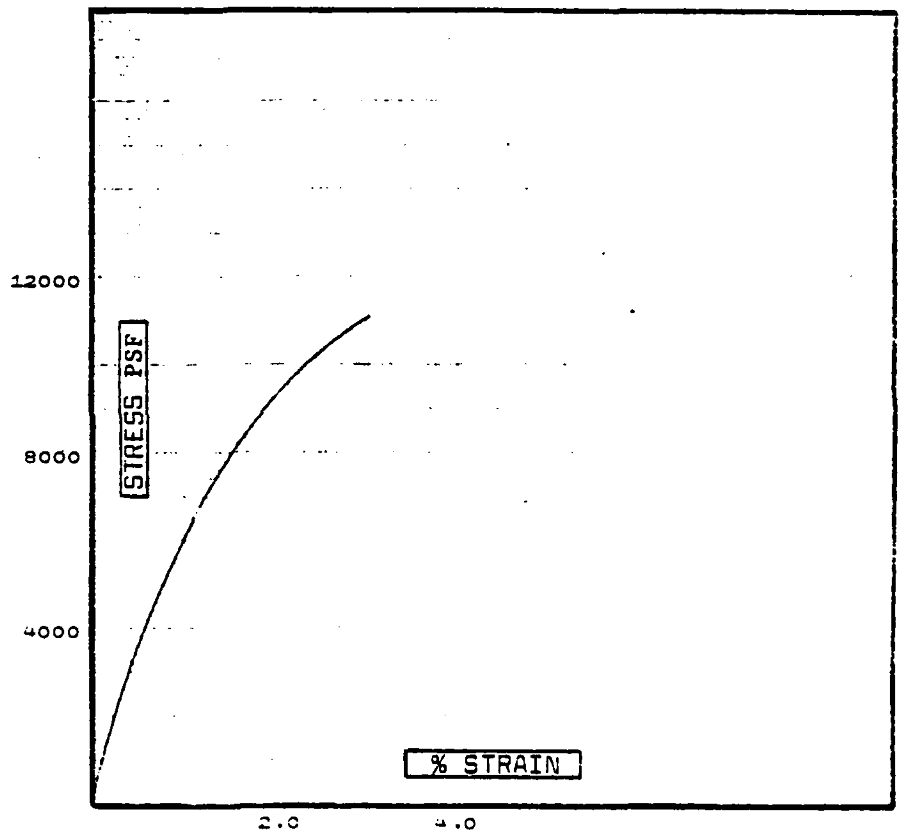
76-017-3-005

BORING NO. D 197 SAMPLE NO. DEPTH: 28.0-30.0 ft.

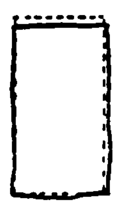
% STRAIN	PSF STRESS
0.4	3236
0.9	5573
1.3	7307
1.8	8619
2.2	9607
2.7	10422
3.1	11012

No failure

UNCONFINED COMPRESSION



FAILURE SKETCH



DESCRIPTION: Light brown slightly silty clay with minor subrounded gravel

DIAMETER: 2.85 in.

HEIGHT: 5.38 in.

MOISTURE: 15.3 percent

UNIT DRY WEIGHT: 115.7 lbs/ft^3

KANSAS CITY TESTING LABORATORY

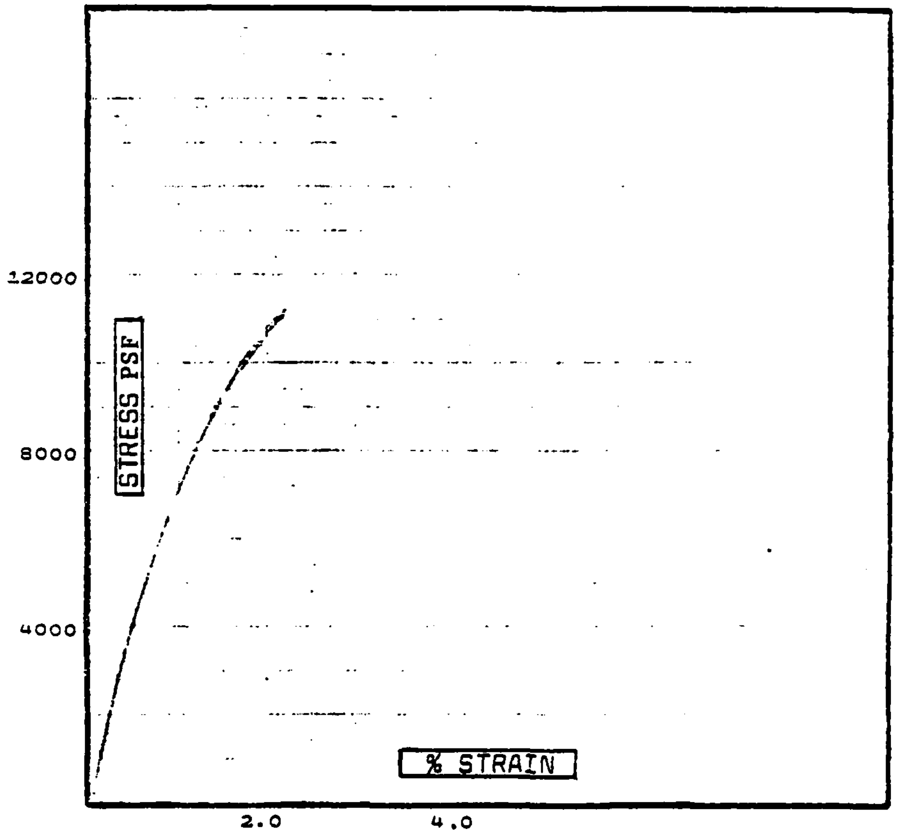
76-017-3-005

BORING NO. D 197 SAMPLE NO. DEPTH: 43.0-45.0 ft.

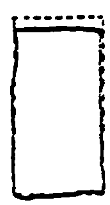
% STRAIN	PSF STRESS
0.4	3528
0.9	6371
1.3	8443
1.8	10035
2.2	11112

No failure

UNCONFINED COMPRESSION



FAILURE SKETCH



DESCRIPTION: Light brown silty clay with calcareous deposits and subangular gravel

DIAMETER: 2.85 in.

HEIGHT: 5.58 in.

MOISTURE: 13.4 percent

UNIT DRY WEIGHT: 118.2 lbs/ft^3

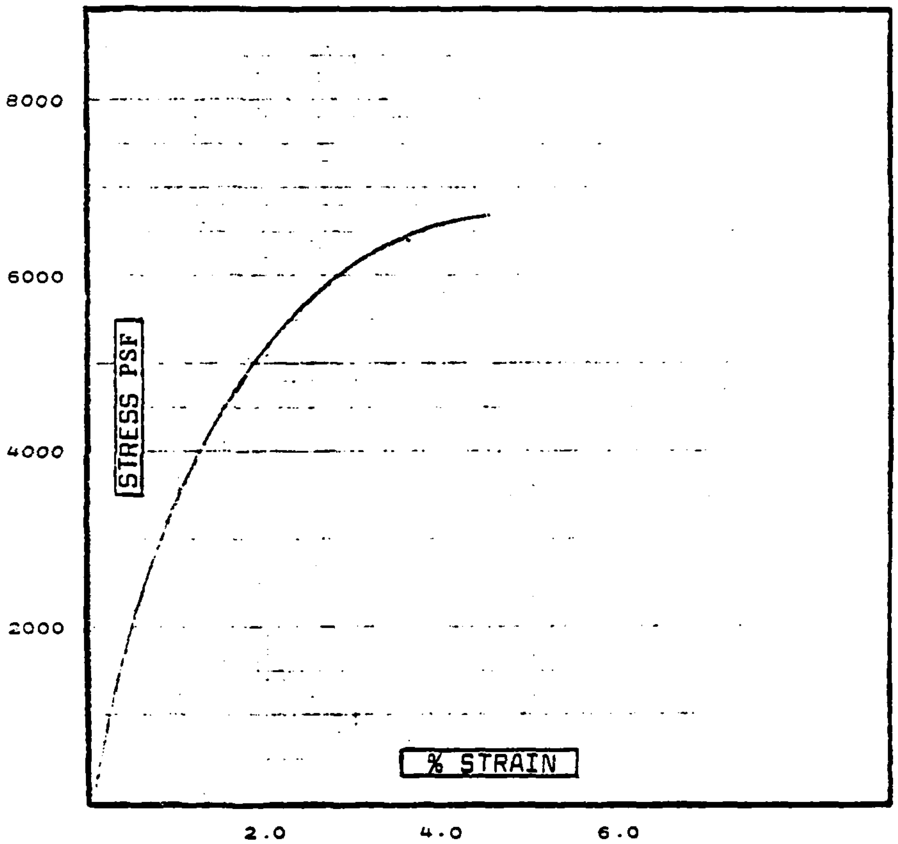
KANSAS CITY TESTING LABORATORY

76-017-3-005

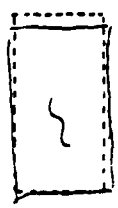
BORING NO. D 197 SAMPLE NO. DEPTH: 63.0-65.0 ft.

% STRAIN	PSF STRESS
0.9	3199
1.8	5017
2.7	5949
3.6	6457
4.5	6701

UNCONFINED COMPRESSION



FAILURE SKETCH



DESCRIPTION: Dark brown silty clay with minor slickensides and iron nodules

DIAMETER: 2.85 in.

HEIGHT: 5.58 in.

MOISTURE: 19.8 percent

UNIT DRY WEIGHT: 108.0 lbs/ft^3

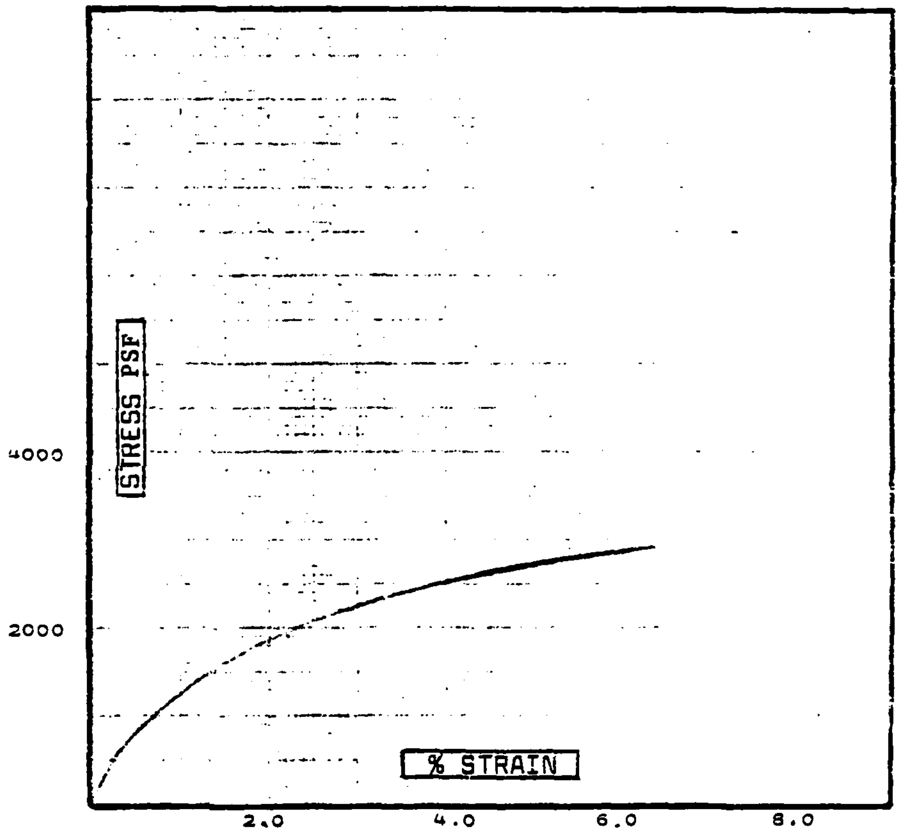
KANSAS CITY TESTING LABORATORY

76-017-3-005

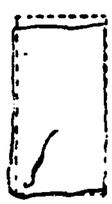
BORING NO. D 197 SAMPLE NO. DEPTH: 73.0-75.0 ft.

% STRAIN	PSF STRESS
0.4	852
1.3	1397
2.2	1911
3.1	2320
4.5	2708
5.4	2915
6.3	2933

UNCONFINED COMPRESSION



FAILURE SKETCH



DESCRIPTION: Gray silty clay with sandy lenses

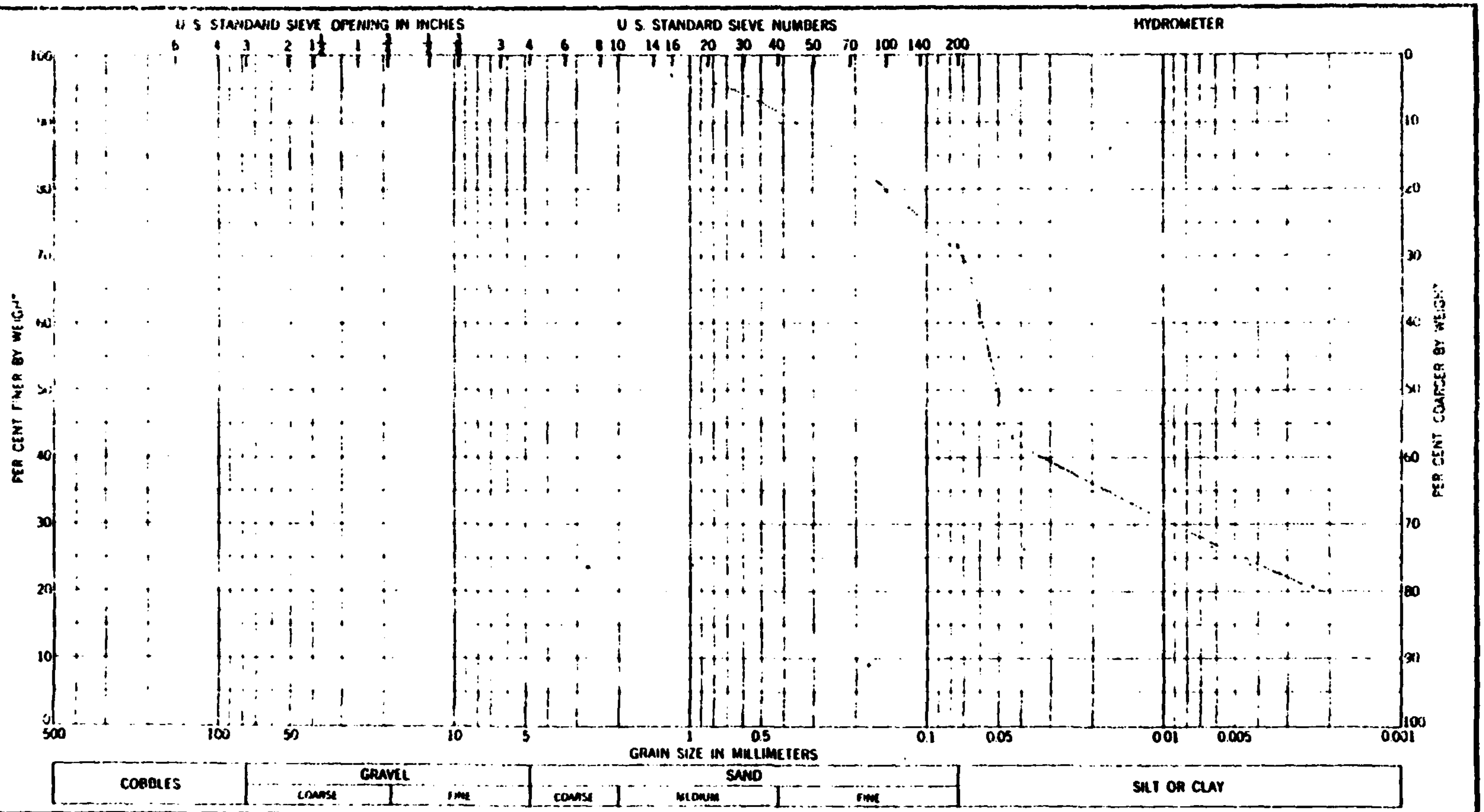
DIAMETER: 2.85 in.

HEIGHT: 5.58 in.

MOISTURE: 24.9 percent

UNIT DRY WEIGHT: 99.4 percent

KANSAS CITY TESTING LABORATORY

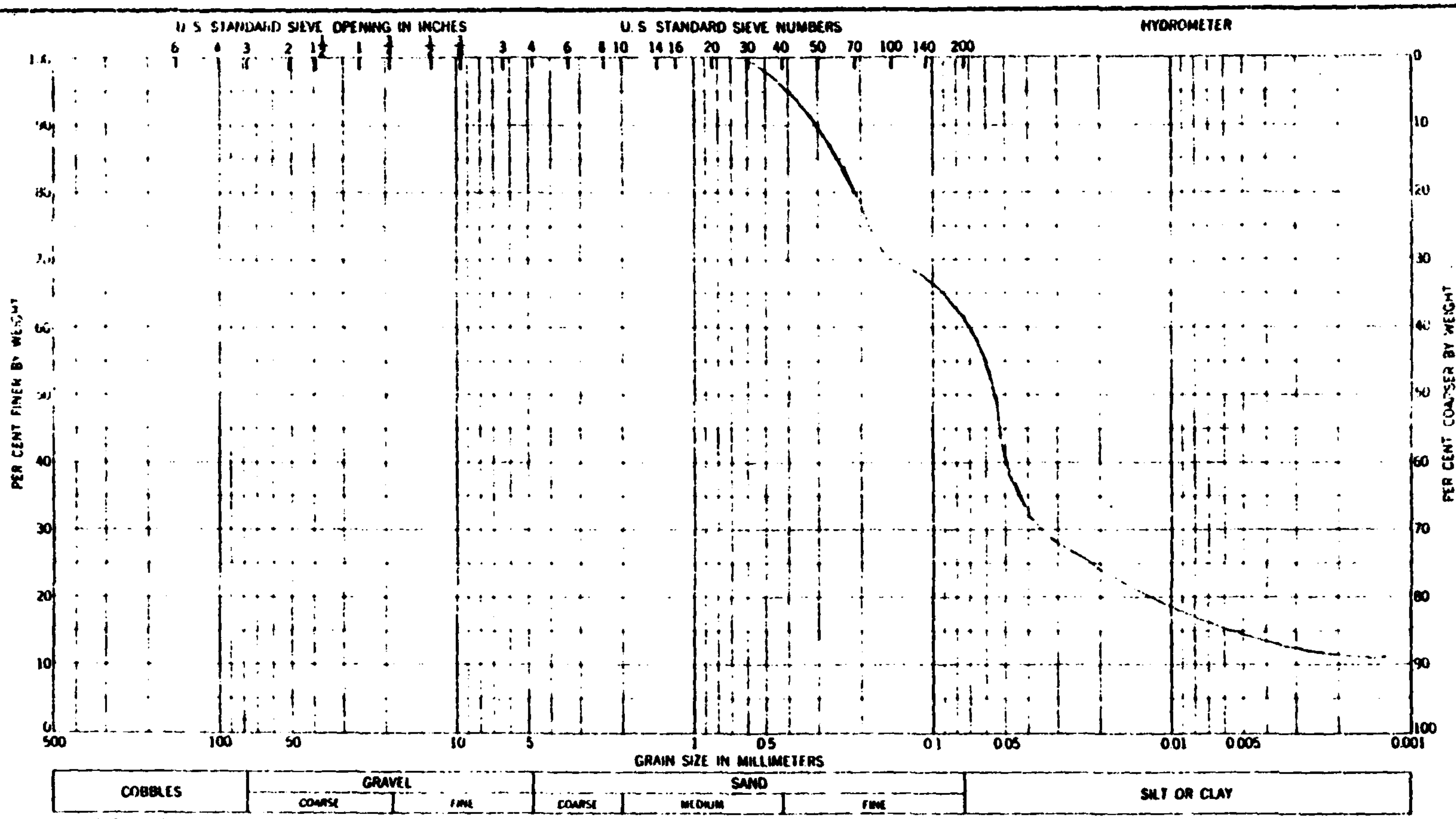


Sample No	Elev or Depth	Classification	Nat w %	LL	PL	PI
	13.0-15.0	CL	15.3	40	16	24

GRADATION CURVES

Project Thomas Hill--Assoc. Elec.
Job No. 76-017-3-005
Area
Boring No D 197
Date 26 Oct, 1977

KANSAS CITY TESTING LABORATORY



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
	68.0-70.0	CL	19.0	27	16	11

Project: Thomas Hill---Assoc. Elec.

Job No. 76-017-3-005

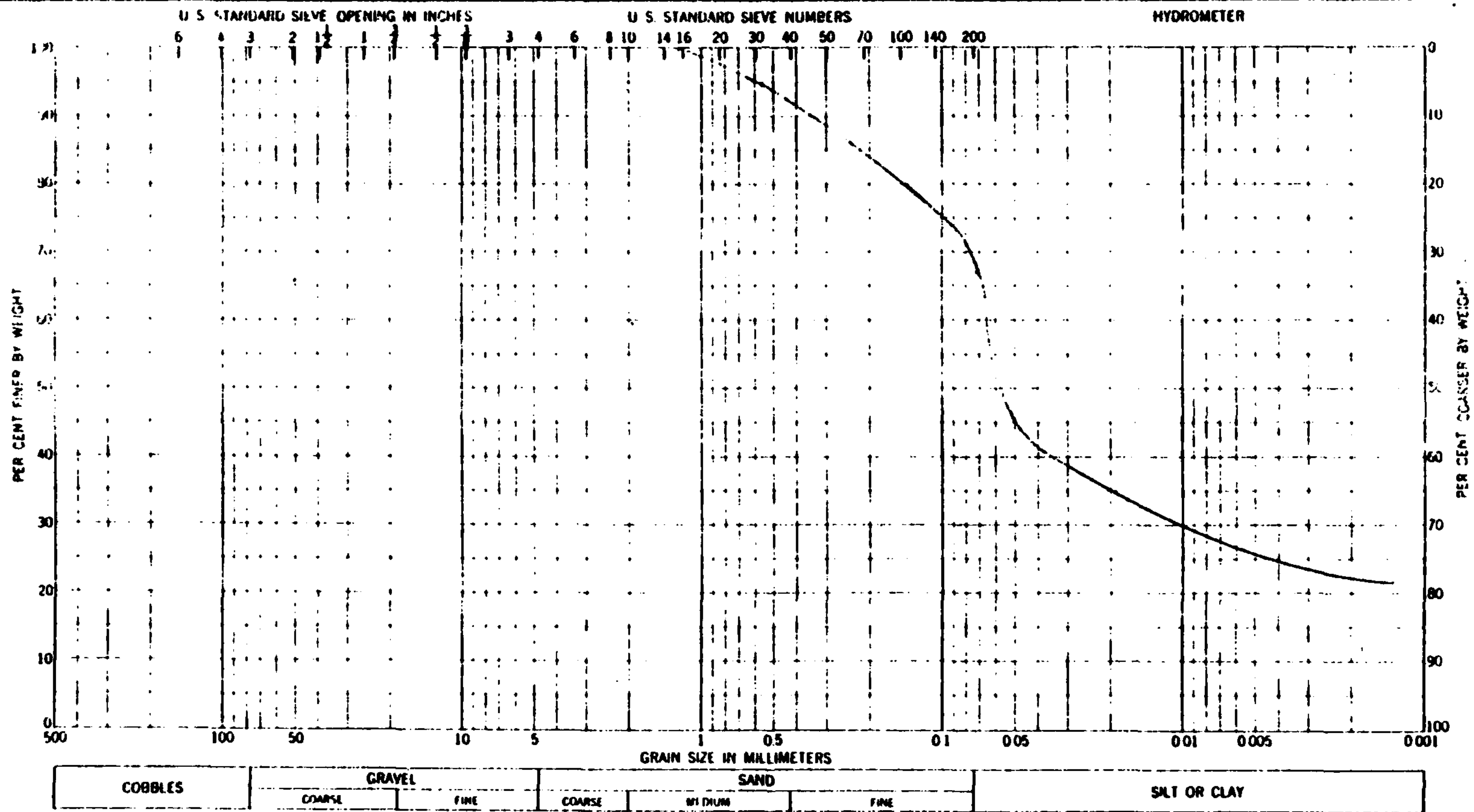
Area

Boring No: D 197

Date: 20 October, 1977

GRADATION CURVES

KANSAS CITY TESTING LABORATORY



Sample No	Elev or Depth	Classification	Nat w %	LL	PL	PI
	8.0-10.0	CL	17.6	41	17	24

GRADATION CURVES

Project Thomas Hill--Assoc. Elec.

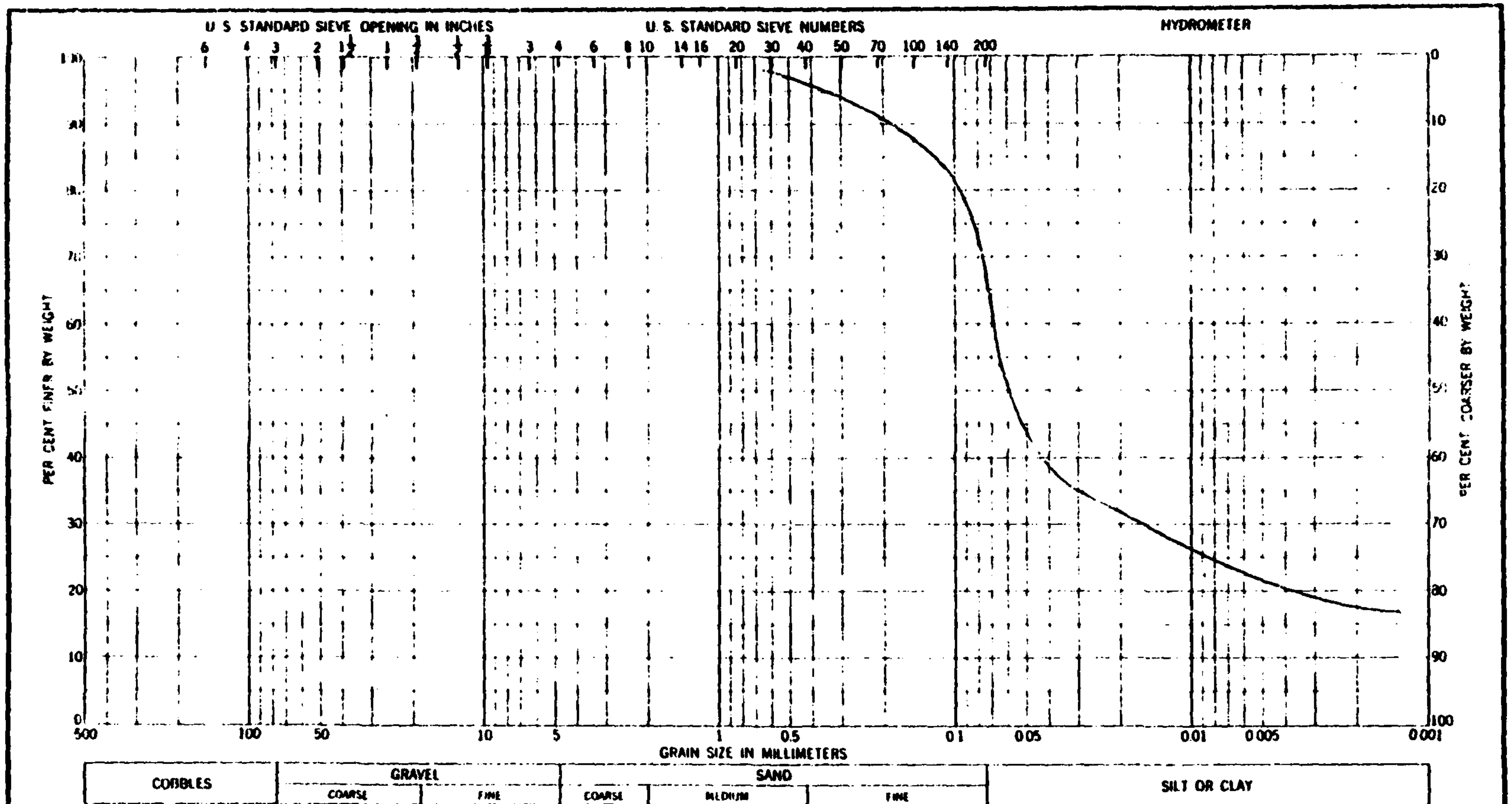
Job No. 76-017-3-005

Area

Boring No D 198

Date 18 Oct, 1977

KANSAS CITY TESTING LABORATORY

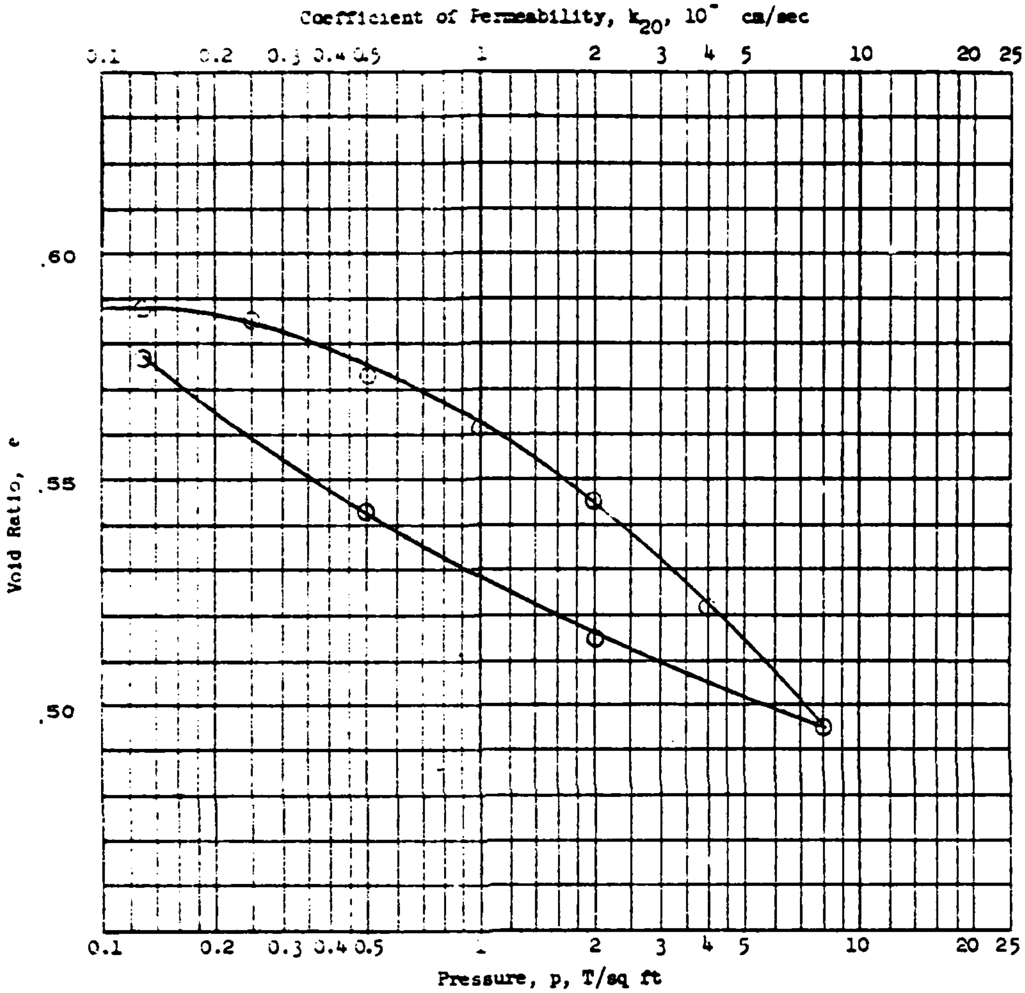


Sample No	Elev or Depth	Classification	Nat w %	LL	PL	PI
	8.0-10.0	CL	19.8	36	14	22

GRADATION CURVES

Project	Thomas Hill--Assoc. Elec.
Job No.	76-017-3-005
Area	
Boring No	D 199
Date	10 Oct, 1977

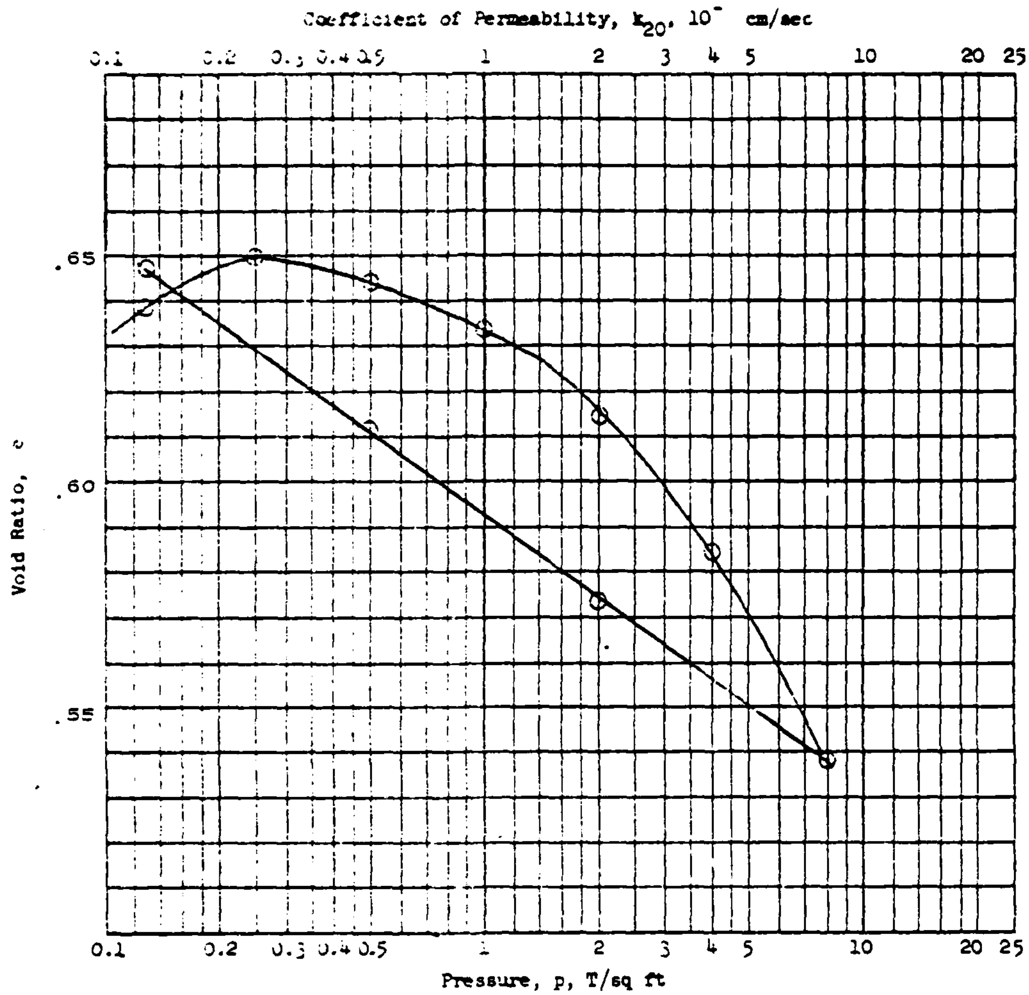
KANSAS CITY TESTING LABORATORY



Type of Specimen undisturbed	Before Test		After Test
Diam 2.0 in. Ht 1.005 in.	Water Content, w_o	22.4 %	w_f 26.1 %
Overburden Pressure, p_o T/sq ft	Void Ratio, e_o	.5840	e_f .5604
Preconsol. Pressure, p_c T/sq ft	Saturation, S_o	101.7 %	S_f 123.4 %
Compression Index, C_c	Dry Density, γ_d	104.9 lb/ft^3	
Classification	k_{20} at e_o =	x 10^{-} cm/sec	
LL G_s 2.65 assumed	Project Thomas Hill	Job No. 76-014-1	
PL PI	Burns and McDonnell		
Remarks Olive and gray	Area		
slightly silty clay with	Boring No. PWP 162	Sample No. ST 2	
limestone nodules	Depth El 5.0-7.0	Date	

CONSOLIDATION TEST REPORT

KANSAS CITY TESTING LABORATORY



Type of Specimen	undisturbed	Before Test		After Test	
Diam 2.0 in.	Ht 1.005 in.	Water Content, w_o	24.5 %	w_f	29.5 %
Overburden Pressure, p_o	T/sq ft	Void Ratio, e_o	.6162	e_f	.7007
Preconsol. Pressure, p_c	T/sq ft	Saturation, S_o	105.3 %	S_f	103.7 %
Compression Index, C_c		Dry Density, γ_d	99.5 lb/ft^3		
Classification		k_{20} at e_o =	x 10- cm/sec		
LL	G_s 2.65 assumed	Project	Thomas Hill	Job No.	76-017-1
PL	PI		Burns and McDonnell		
Remarks	Brown silty clay	Area			
		Boring No.	ST 166	Sample No.	S 2
		Depth El	8.0-10.0 ft.	Date	

CONSOLIDATION TEST REPORT

AD-A105 332 HOSKINS-WESTERN-SONDEREGGER INC LINCOLN NE F/G 13/13
NATIONAL DAM SAFETY PROGRAM. THOMAS HILL RESERVOIR DAM (MO 1013--ETC(U)
MAY 80 R S DECKER, G JAMISON, G ULMER DACW43-80-C-0071

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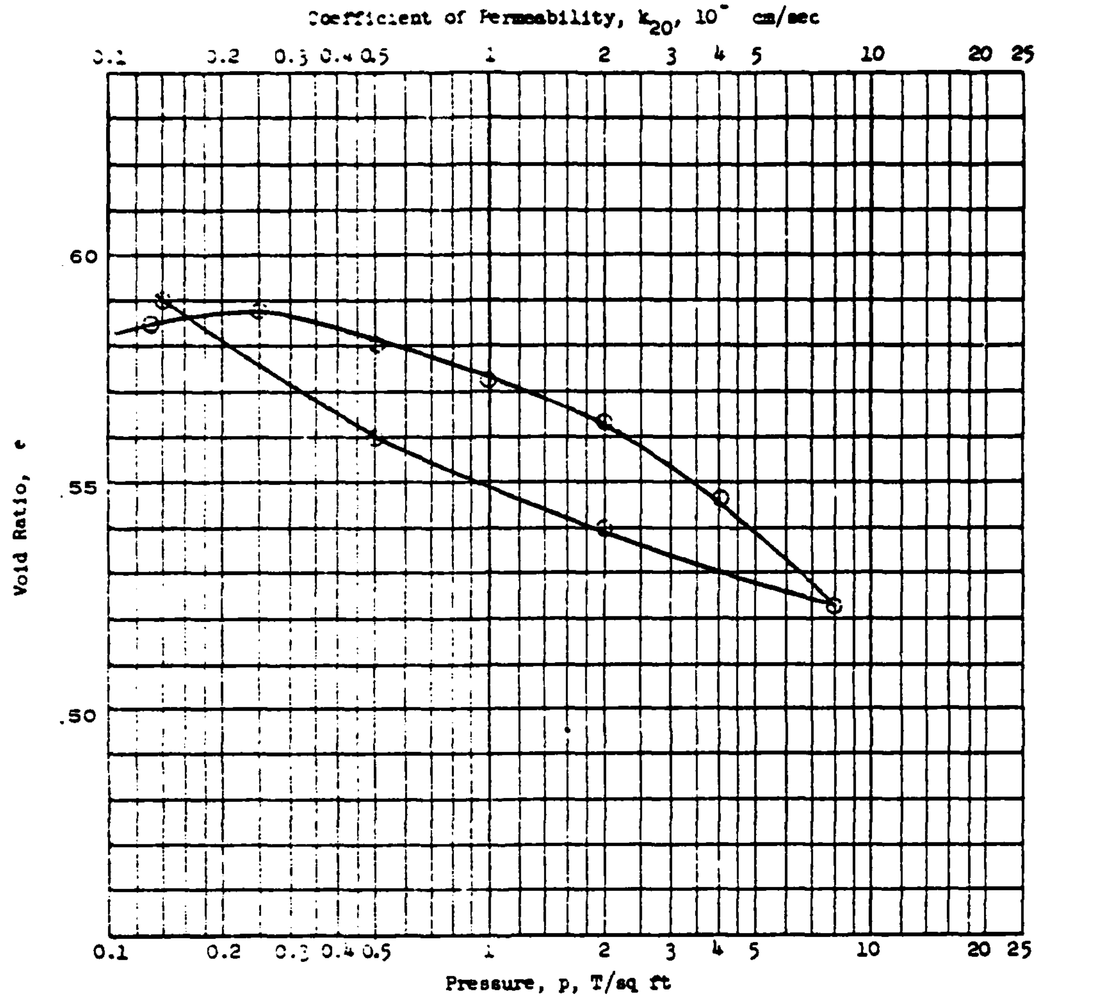
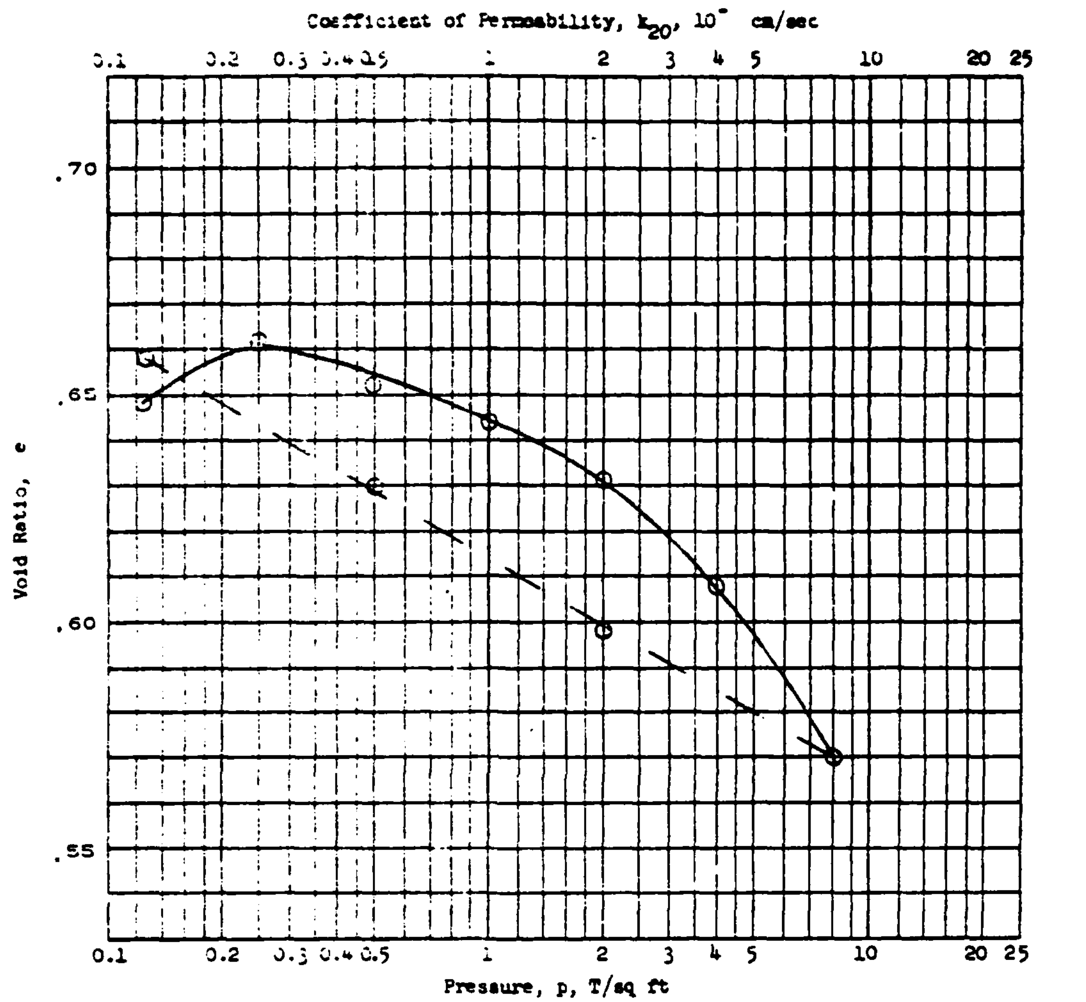
KANSAS CITY TESTING LABORATORY



Type of Specimen undisturbed		Before Test		After Test	
Diam 2.0 in.	Ht .9972 in.	Water Content, w_o	22.0 %	w_f	26.1 %
Overburden Pressure, p_o T/sq ft		Void Ratio, e_o	.5701	e_f	.6379
Preconsol. Pressure, p_c T/sq ft		Saturation, S_o	102.3 %	S_f	108.4 %
Compression Index, C_c		Dry Density, γ_d	105.8 lb/ft^3		
Classification		k_{20} at e_o = × 10^{-} cm/sec			
LL	G_s 2.65 assumed	Project Thomas Hill		Job No. 76-017-1	
PL		Burns and McDonnell			
Remarks Brown silty clay		Area			
		Boring No. WA 176		Sample No. S 1	
		Depth 3.5-5.5 ft.		Date	

CONSOLIDATION TEST REPORT

KANSAS CITY TESTING LABORATORY



Type of Specimen undisturbed		Before Test		After Test	
Diam 2.0 in.	Ht 1.002 in.	Water Content, w_o	23.2 %	w_f	26.1 %
Overburden Pressure, p_o T/sq ft		Void Ratio, e_o	0.622	e_f	0.668
Preconsol. Pressure, p_c T/sq ft		Saturation, S_o	98.8 %	S_f	103.5 %
Compression Index, C_c		Dry Density, γ_d	102.4 lb/ft³		
Classification CL		k_{20} at e_o = × 10^{-} cm/sec			
LL 46	G_s 2.65 assumed	Project Thomas Hill		Job No. 76-017-1	
PL 15	PI	Burns and McDonnell			
Remarks Brown silty clay with iron nodules and calcite deposits		Area			
		Boring No. SB 209		Sample No. ST 1	
		Depth El 4.0-6.0 ft.		Date	

CONSOLIDATION TEST REPORT

KANSAS CITY TESTING LABORATORY

Burns and McDonnell
Assoc. Elec.--Thomas Hill
76-017-1

PERMEABILITY TEST DATA

Boring No	Sample No	Depth, ft	% Moisture Initial	% Moisture Final	Density PCF	k x 10 ⁶
D 197	ST 7	33.0-35.0	15.3	23.1	115.1	0.15
D 197	ST 13	63.0-65.0	20.9	21.8	104.9	0.28
D 197	ST 15	73.0-75.0	15.5	23.3	108.7*	0.72
D 198	ST 3	13.0-15.0	0	17.8	101.0*	270

Boring No	Sample No	Depth, ft	Days Saturated	Description
D 197	ST 7	33.0-35.0	18	Light brown mottled gray silty clay with calcareous deposits
D 197	ST 13	63.0-65.0	14	Dark brown silty clay with minor slickensides and iron nodules
D 197	ST 15	73.0-75.0	13	Gray silty clay with sand lenses
D 198	ST 3	13.0-15.0	6	Tan, medium grained sand

*sample remolded

KANSAS CITY TESTING LABORATORY

TRIAXIAL COMPRESSION

MOHR STRESS ENVELOPE

R-TEST

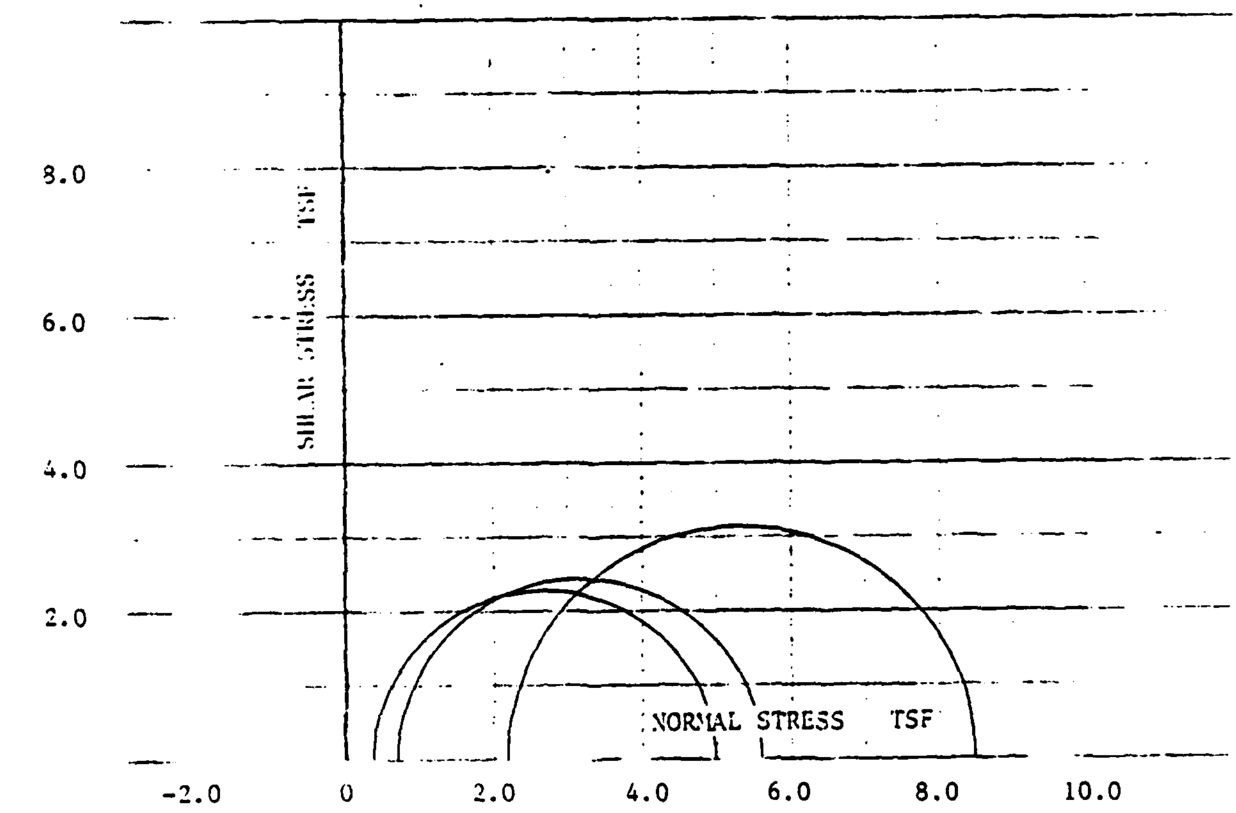
PROJECT: Thomas Hill

PROJECT NO: 76-017-3-005

BORING NO: D 197

DEPTH: 13.0-15.0 ft.

DESCRIPTION: Brown mottled gray silty clay with sand and gravel. Sample no 3 had slickensides



SAMPLE NO	1	2	3
% MOISTURE	15.3	16.2	16.3
UNIT DRY WT. PCF	116.7	116.7	114.1
CONFINING PRESSURE TSF	0.36	0.71	2.16
MAXIMUM STRESS TSF	4.65	4.86	6.41
% AXIAL STRAIN	9.0	12.5	7.2

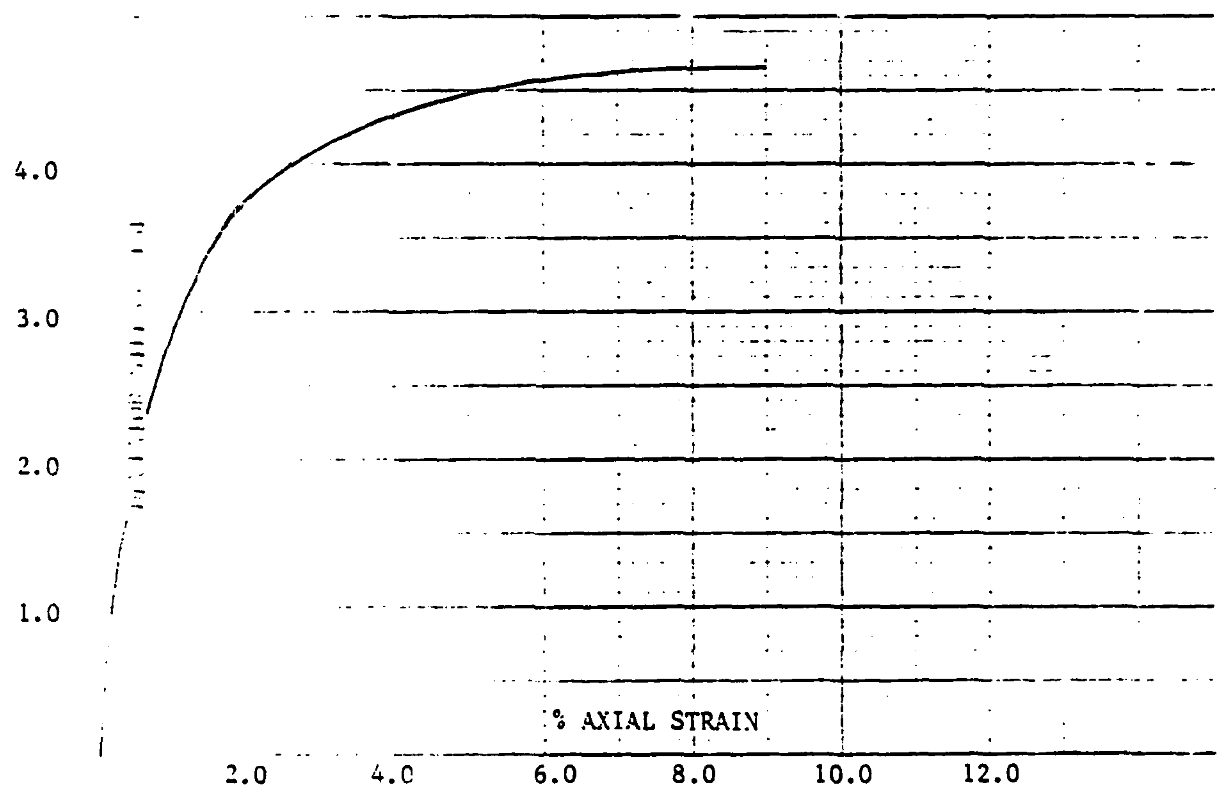
KANSAS CITY TESTING LABORATORY

TRIAXIAL COMPRESSION

STRESS-STRAIN RELATIONSHIP

[illegible]: Thomas Hill PROJECT NO: 76-017-3-005

[illegible]: D 197 SAMPLE NO: ST 3 1 DEPTH: 13.0-15.0 ft.



2.85 in. HEIGHT: 5.58 in.

15.3 percent UNIT DRY WEIGHT: 116.7 lbs/ft^3

5 PSI NATURAL X REMOLDED ____

4.65 TSF AXIAL STRAIN: 9.0 percent

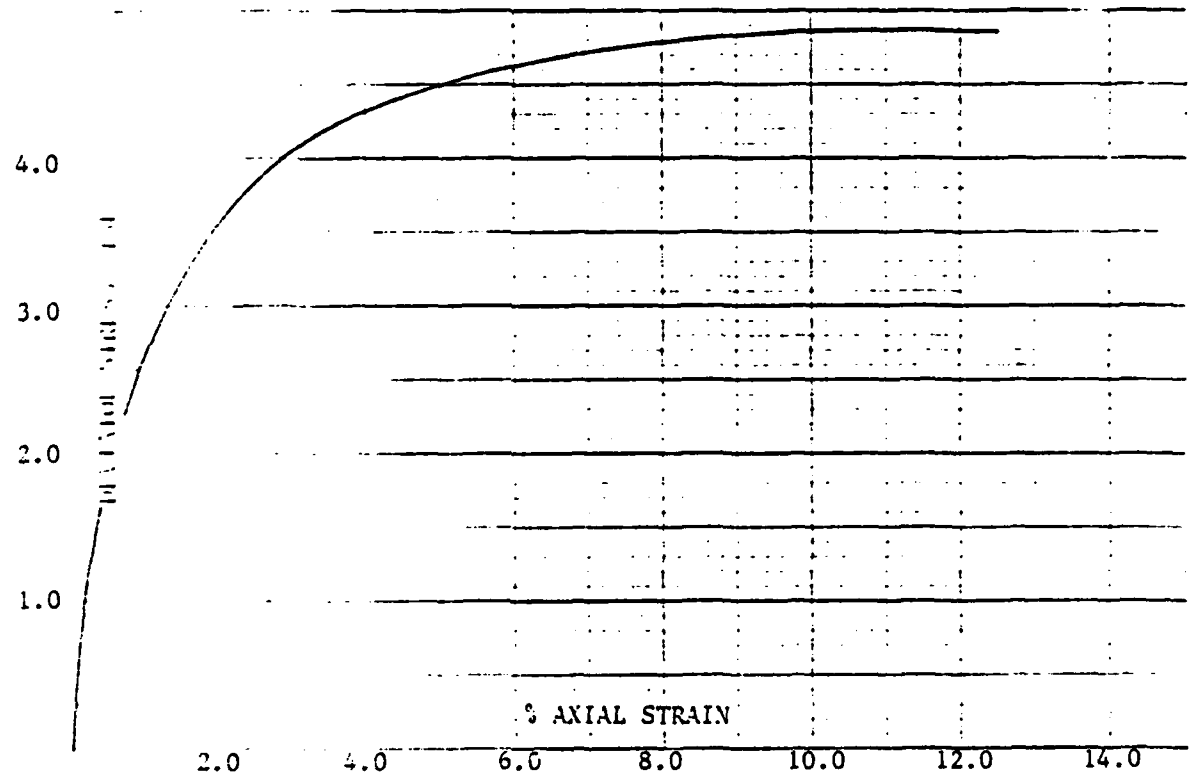
KANSAS CITY TESTING LABORATORY

TRIAXIAL COMPRESSION

STRESS-STRAIN RELATIONSHIP

PROJECT: Thomas Hill PROJECT NO: 76-017-3-005

BORING NO: D 197 SAMPLE NO: ST 3 2 DEPTH: 13.0-15.0 ft.



2.85 in. HEIGHT: 5.58 in.

16.2 percent UNIT DRY WEIGHT: 116.7 lbs/ft^3

: 10 PSI NATURAL X REMOLDED ____

4.86 TSF AXIAL STRAIN: 12.5 percent

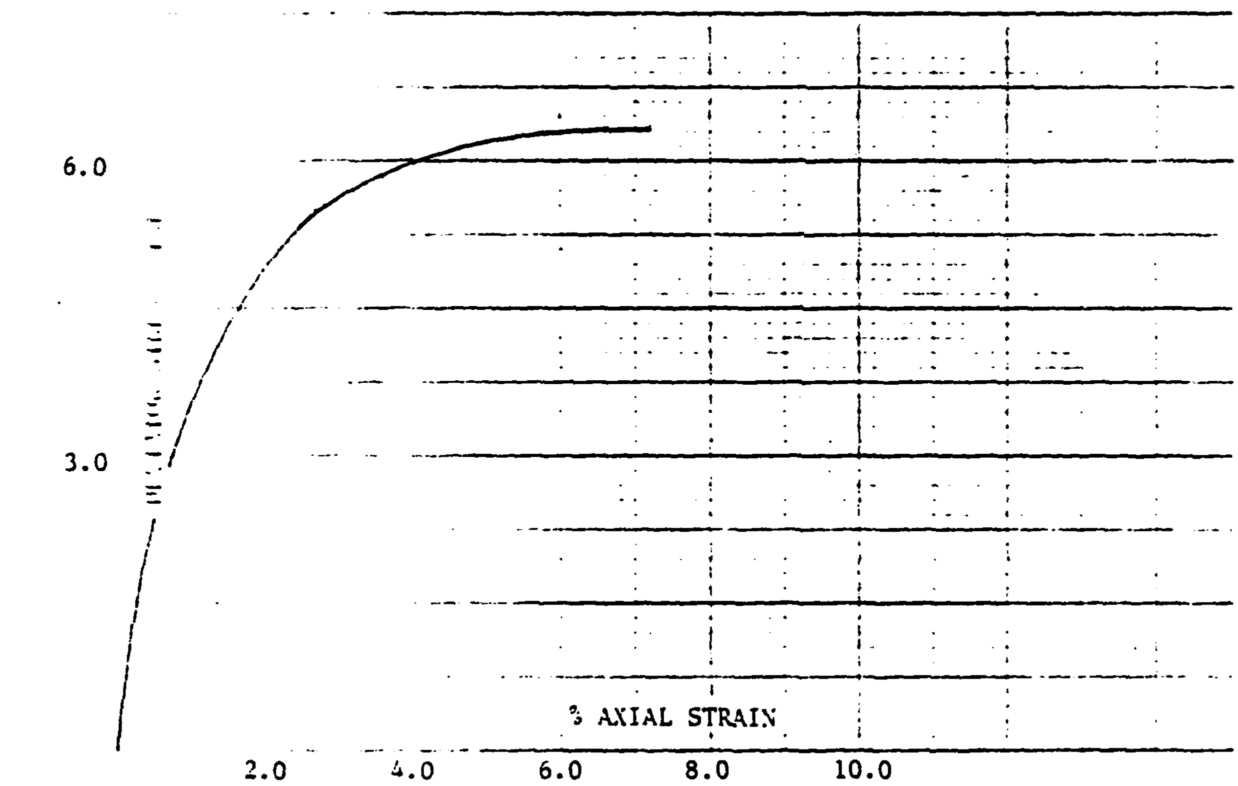
KANSAS CITY TESTING LABORATORY

TRIAXIAL COMPRESSION

STRESS-STRAIN RELATIONSHIP

PROJECT: Thomas Hill PROJECT NO: 76-017-3-005

BORING NO: D 197 SAMPLE NO: ST 3 3 DEPTH: 13.0-15.0 ft.



2.35 in. HEIGHT: 5.58 in.

16.3 percent UNIT DRY WEIGHT: 114.1 lbs/ft^3

30 PSI NATURAL X REMOLDED ____

6.41 TSF AXIAL STRAIN: 7.2 percent

KANSAS CITY TESTING LABORATORY

TRIAXIAL COMPRESSION

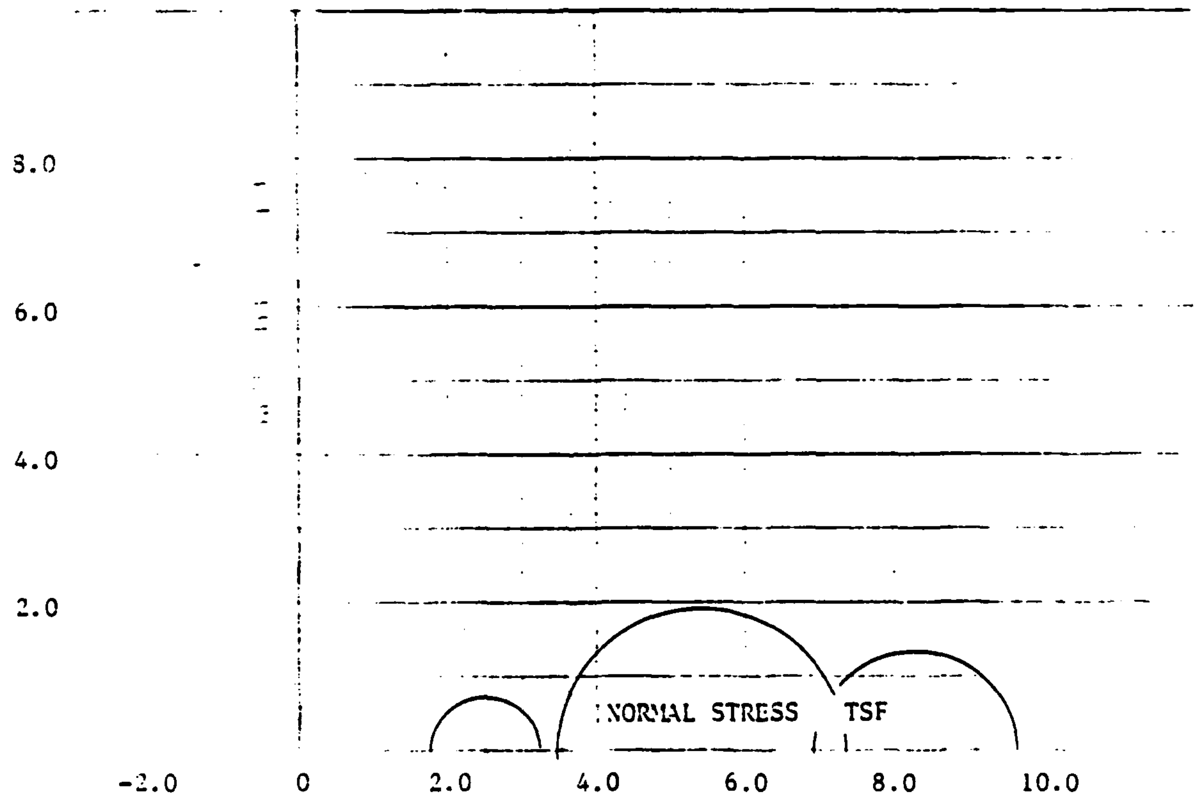
MOHR STRESS ENVELOPE

R-TEST

PROJECT: Thomas Hill PROJECT NO: 76-017-3-005

BORING: D 197 DEPTH: 68.0-70.0 ft.

Gray mottled rust, sandy, silty clay with sand lenses



1	2	3
19.3	19.0	23.1
105.6	104.0	104.3
1.73	3.46	6.91
1.52	3.90	2.72
17.6	16.9	17.6

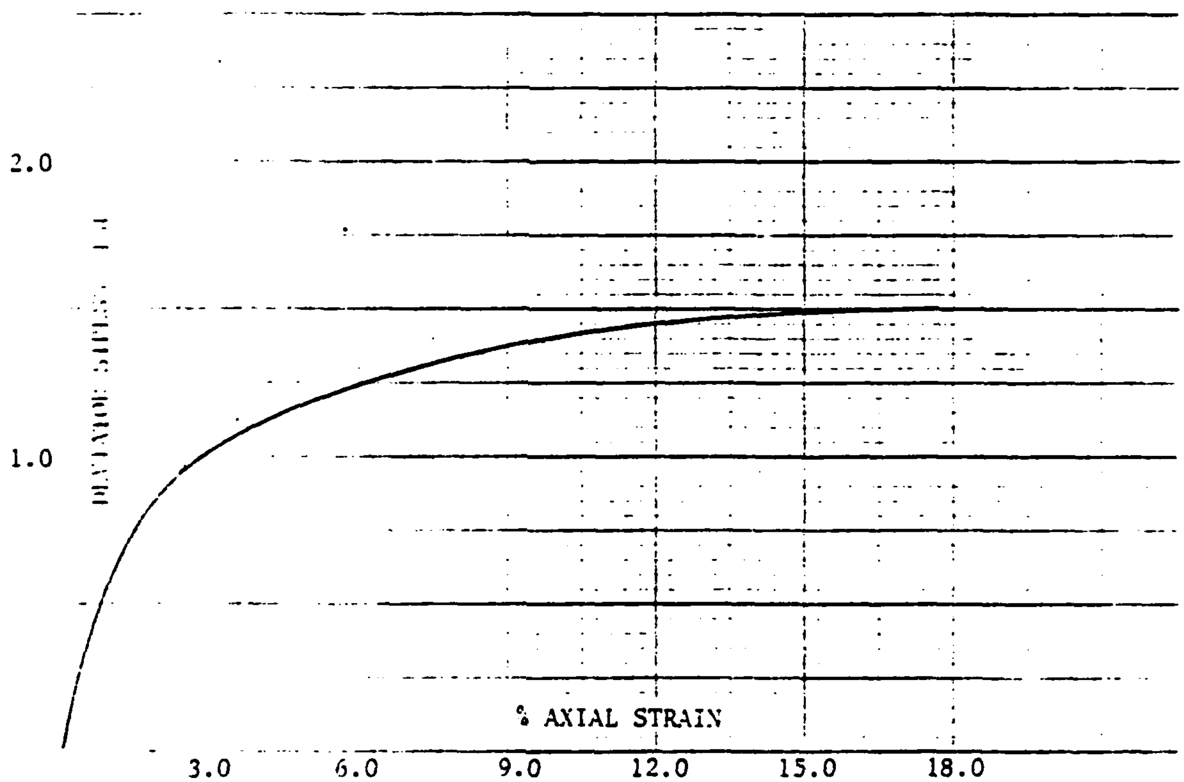
KANSAS CITY TESTING LABORATORY

TRIAXIAL COMPRESSION

STRESS-STRAIN RELATIONSHIP

PROJECT: Thomas Hill PROJECT NO: 76-017-3-005

BORING NO: D 197 SAMPLE NO: ST 14 1 DEPTH: 68.0-70.0 ft.



2.85 in. HEIGHT: 5.58 in.

19.3 percent UNIT DRY WEIGHT: 105.6 lbs/ft³

24 PSI NATURAL X REMOLDED ____

1.52 TSF AXIAL STRAIN: 17.6 percent

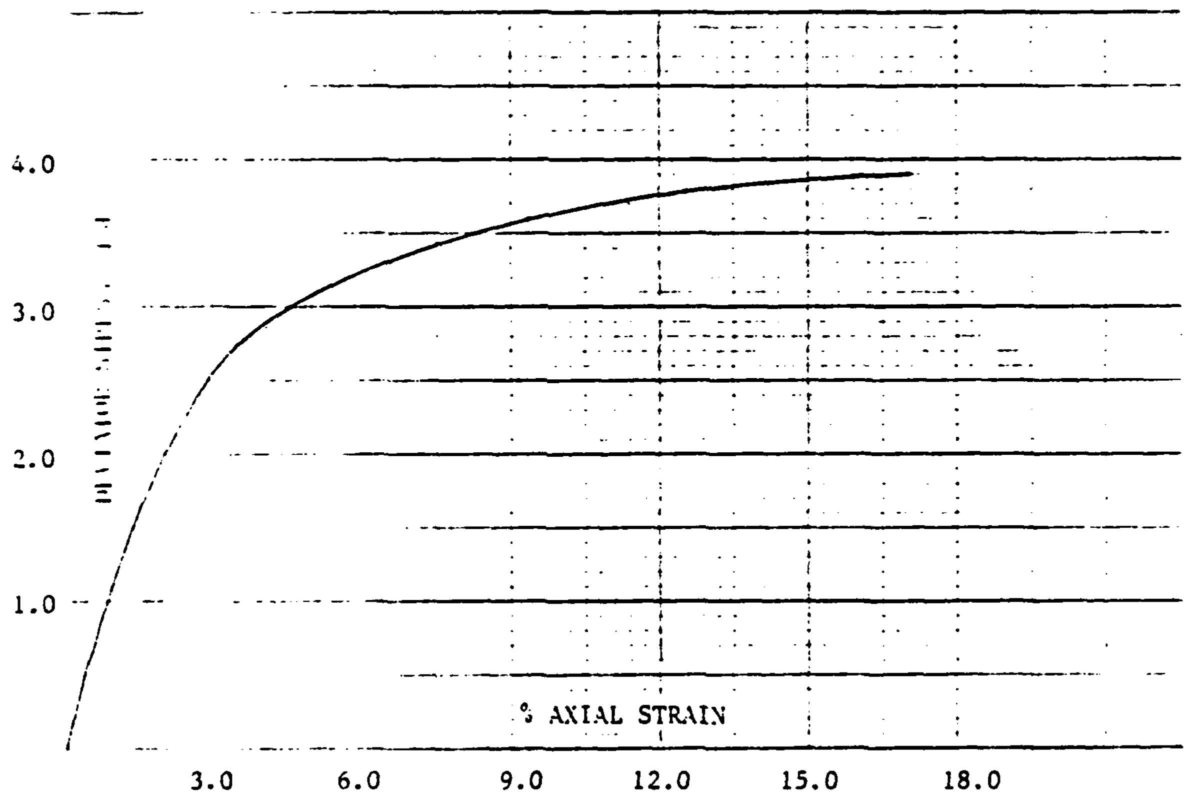
KANSAS CITY TESTING LABORATORY

TRIAXIAL COMPRESSION

STRESS-STRAIN RELATIONSHIP

PROJECT: Thomas Hill PROJECT NO: 76-017-3-005

BORING NO: D 197 SAMPLE NO: ST 14 2 DEPTH: 68.0-70.0 ft.



2.85 in. HEIGHT: 5.58 in.

19.0 percent UNIT DRY WEIGHT: 104.0 lbs/ft^3

48 PSI NATURAL X REMOLDED ____

3.90 TSF AXIAL STRAIN: 16.9 percent

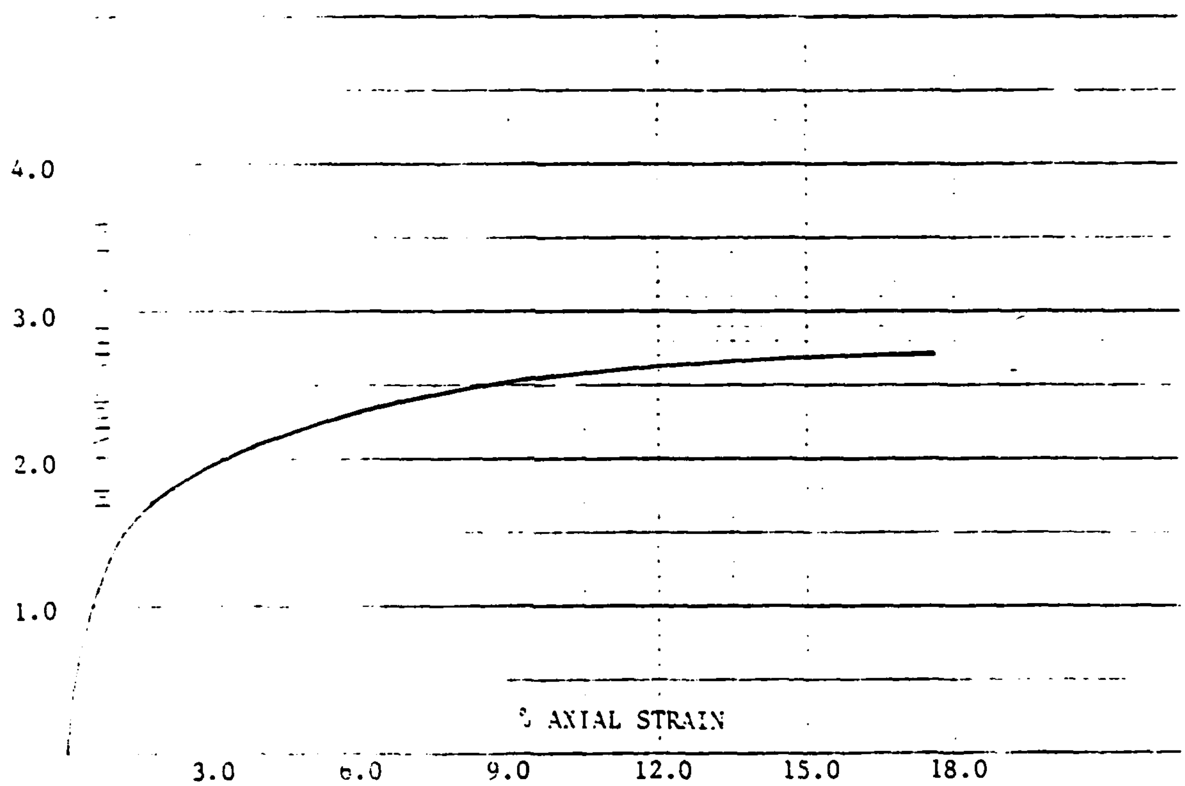
KANSAS CITY TESTING LABORATORY

TRIAXIAL COMPRESSION

STRESS-STRAIN RELATIONSHIP

Thomas Hill PROJECT NO: 76-017-3-005

D 197 SAMPLE NO: ST 14 3 DEPTH: 68.0-70.0 ft.



2.85 in. HEIGHT: 5.58 in.

23.1 percent UNIT DRY WEIGHT: 104.3 lbs/ft^3

96 PSI NATURAL X REMOLDED ___

2.72 TSF AXIAL STRAIN: 17.6 percent

KANSAS CITY TESTING LABORATORY

TRIAXIAL COMPRESSION

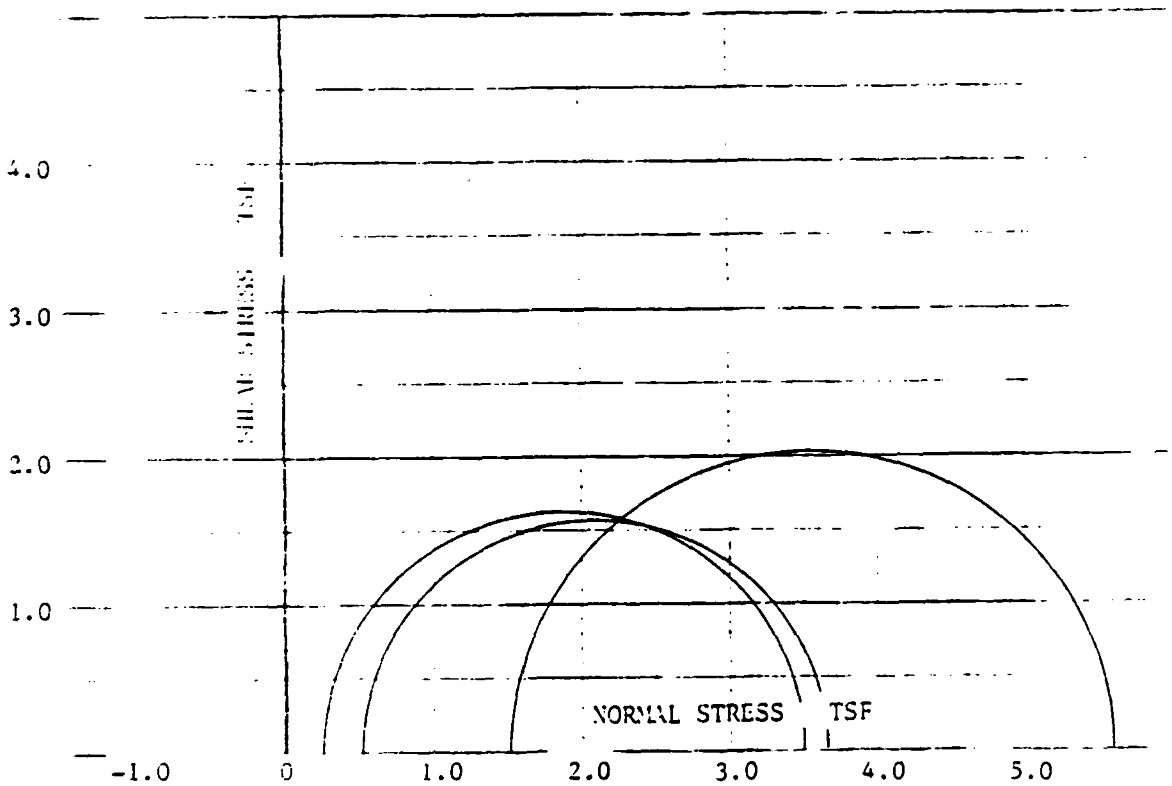
MOHR STRESS ENVELOPE

R-TEST

PROJECT: Thomas Hill   PROJECT NO: 76-017-3-005

BORING NO: D 198   DEPTH: 8.0-10.0 ft.

DESCRIPTION: Brown, tan and gray mottled silty clay with sand and minor gravel



SAMPLE NO	1	2	3
MOISTURE	17.6	17.5	18.1
UNIT DRY WT	114.2	113.4	112.1
CONFINING PRESS TSF	0.25	0.50	1.51
MAXIMUM STRESS	3.27	3.14	4.07
AXIAL STRAIN	10.8	12.5	12.5

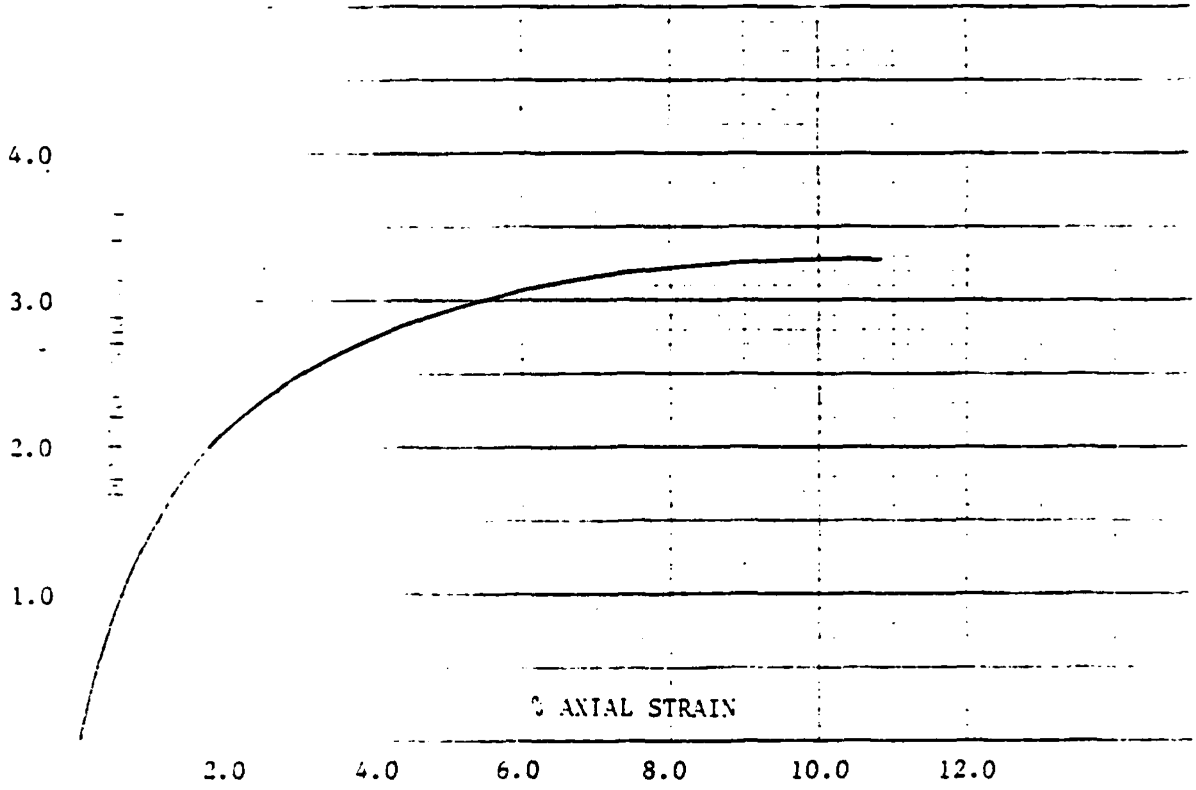
KANSAS CITY TESTING LABORATORY

TRIAXIAL COMPRESSION

STRESS-STRAIN RELATIONSHIP

[illegible] Thomas Hill PROJECT NO: 76-017-3-005

[illegible] D 198 SAMPLE NO: ST 2 1 DEPTH: 8.0-10.0 ft.



2.85 in. HEIGHT: 5.58 in.

17.6 percent UNIT DRY WEIGHT: 114.2 lbs/ft^3

3.5 PSI NATURAL X REMOLDED ____

3.27 TSF AXIAL STRAIN: 10.8 percent

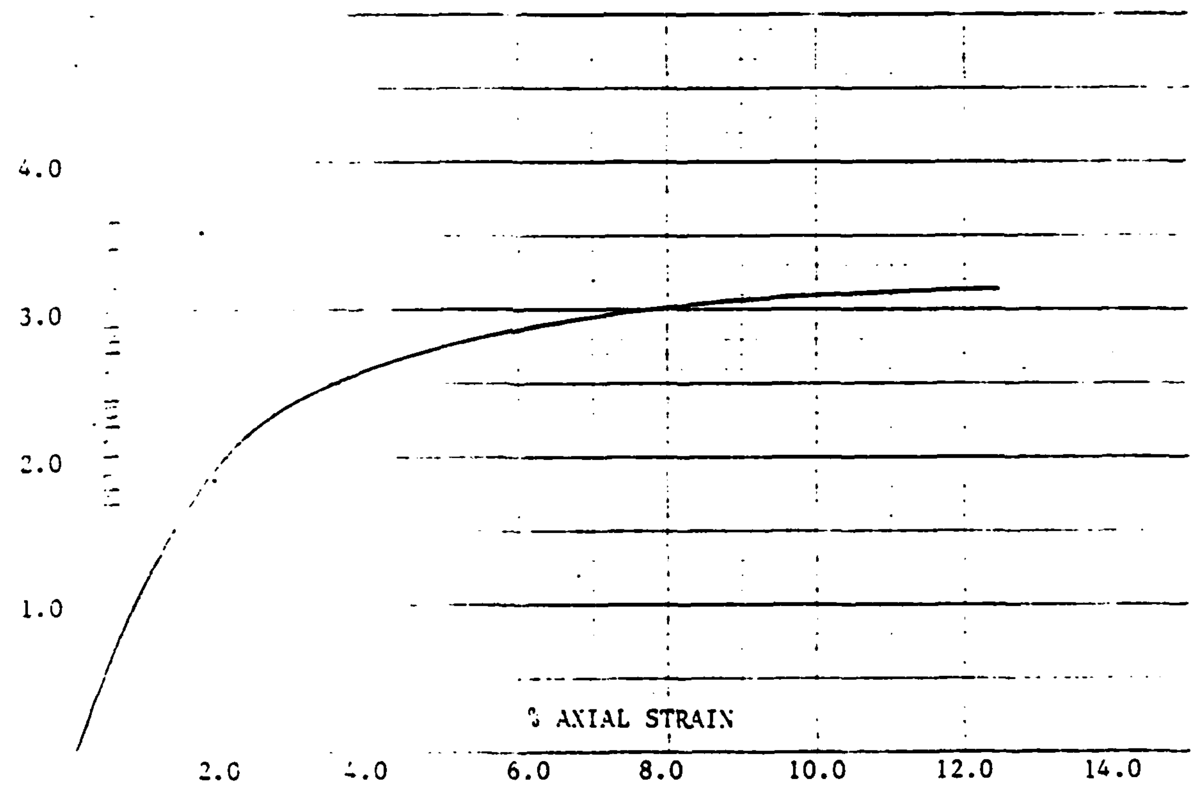
KANSAS CITY TESTING LABORAT[illegible]

TRIAXIAL COMPRESSION

STRESS-STRAIN RELATIONSHIP

[illegible] Thomas Hill — PROJECT NO: 76-017-3-005

[illegible] D 198 — SAMPLE NO: ST 2 2 — DEPTH: 8.0-10.0 ft.



[illegible] 2.85 in. — HEIGHT: 5.58 in.

[illegible] 17.5 percent — UNIT DRY WEIGHT: 113.4 lbs/ft³

7 PSI — NATURAL X REMOLDED ____

3.14 TSF — AXIAL STRAIN: 12.5 percent

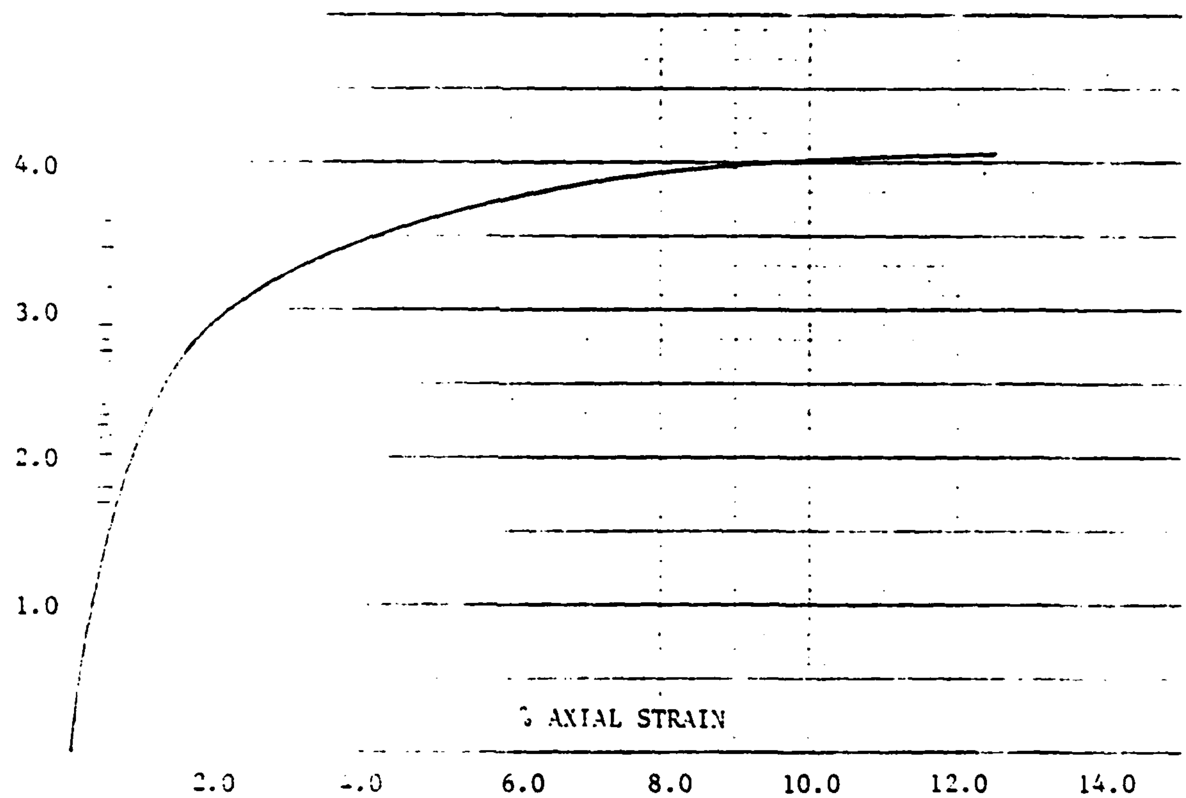
KANSAS CITY TESTING LABORATORY

TRIAXIAL COMPRESSION

STRESS-STRAIN RELATIONSHIP

Thomas Hill PROJECT NO: 76-017-3-005

D 198 SAMPLE NO: ST 2 3 DEPTH: 8.0-10.0 ft.



2.35 in. HEIGHT: 5.58 in.

19.1 percent UNIT DRY WEIGHT: 112.1 lbs/ft³

11 PSI NATURAL X REMOLDED ____

4.07 TSF AXIAL STRAIN: 12.5 percent

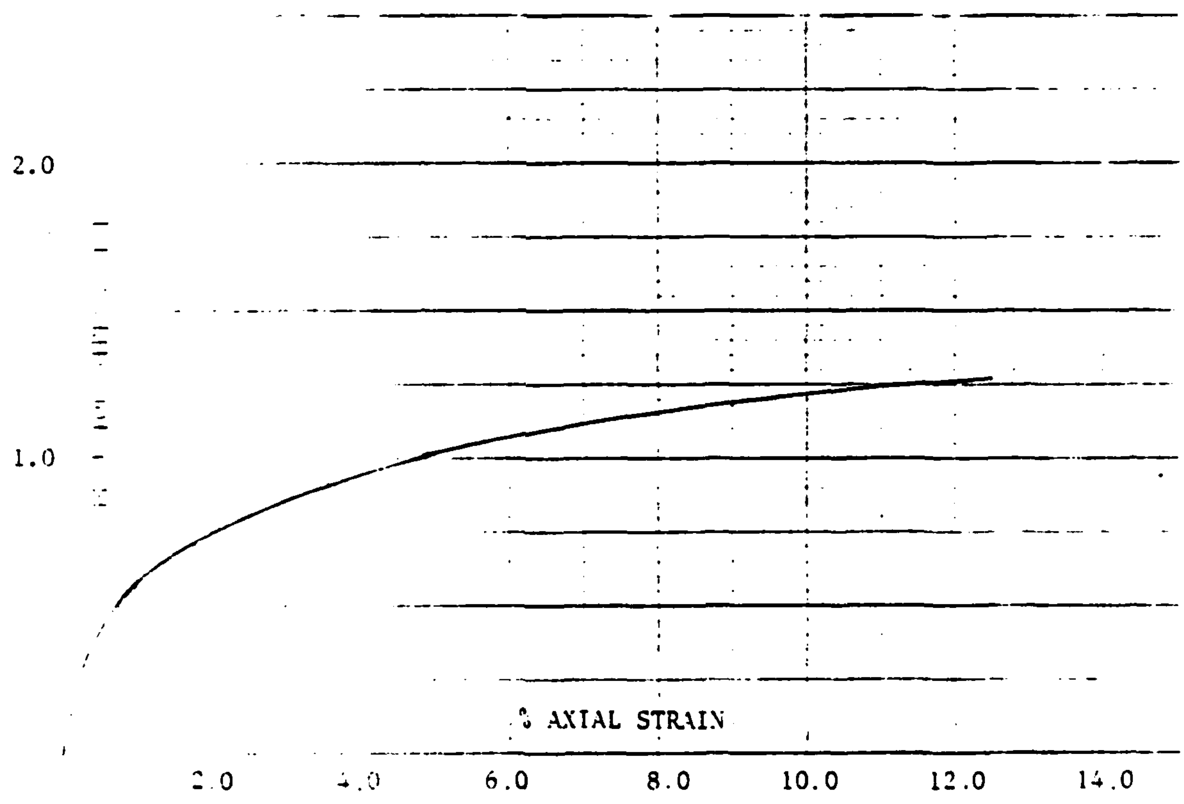
KANSAS CITY TESTING LABORATORY

TRIAXIAL COMPRESSION

STRESS-STRAIN RELATIONSHIP
R-test

PROJECT: Thomas Hill PROJECT NO: 76-017-3-005

BORING NO: D 199 SAMPLE NO: ST 2 DEPTH: 8.0-10.0 ft.



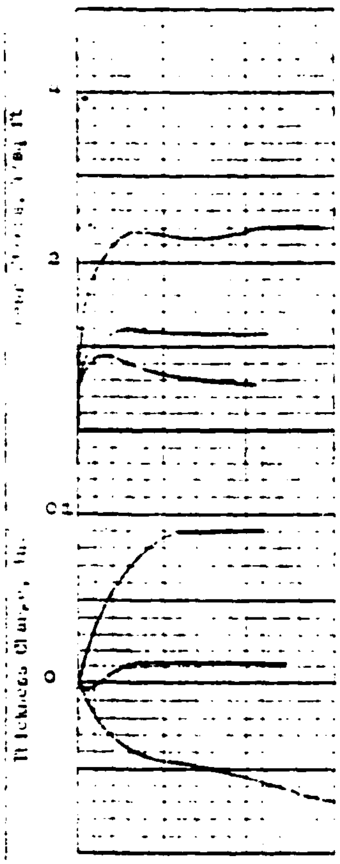
[illegible] in. HEIGHT: 5.58 in.

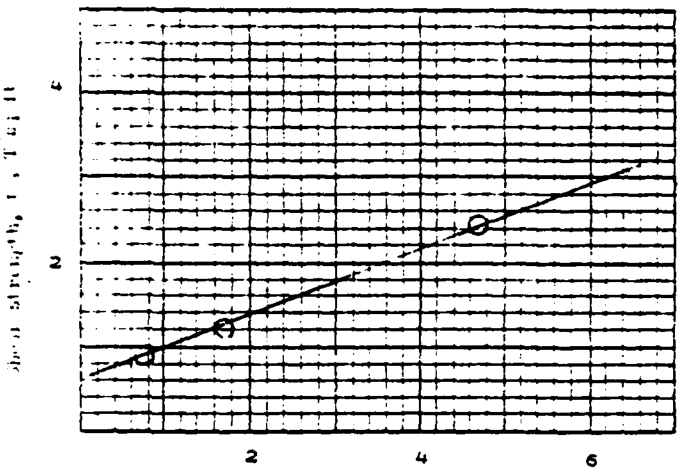
19.8 percent UNIT DRY WEIGHT: 107.0 lbs/ft^3

[illegible] PSI NATURAL X REMOLDED ____

1.26 TSF AXIAL STRAIN: 12.5 percent

KANSAS CITY TESTING LABORATORY





Test No.			1	2	3	
Initial	Water content	w_o	17.7%	14.6 %	14.0 %	%
	Void ratio	e_o	.546	.463	.454	
	Saturation	S_o	86.9%	84.5%	70.8%	%
	Dry density lb/cu ft	γ_d	108.6	114.8	115.5	
Void ratio after consolidation		e_c	.546	.440	.420	
Time for 50% consolidation, min		t_{50}	<0.5	<0.5	<0.5	
Final	Water content	w_f	22.9%	16.1 %	16.2 %	%
	Void ratio	e_f	.552	.440	.408	
	Saturation	S_f	111.2%	98.1 %	106.4%	%
Actual time to failure, min.		t_f	55	90	350	
Normal stress T/sq ft		σ	0.774	1.750	4.694	
Maximum shear strength, T/sq ft		τ	0.921	1.180	2.426	

Shear Values

φ ______

tan φ ______

c 0.6 TSF

☐ Controlled stress ☒ Controlled strain

4.904 in. Square | 1.0 in. Thickness

Olive brown silty clay Thomas Hill 76-017-3-005

with sand and gravel Burns and McDonnell

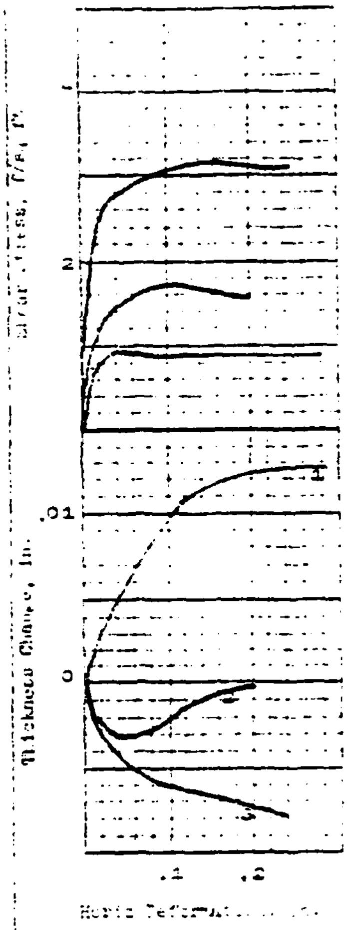
Pre-test: consolidated 3 days

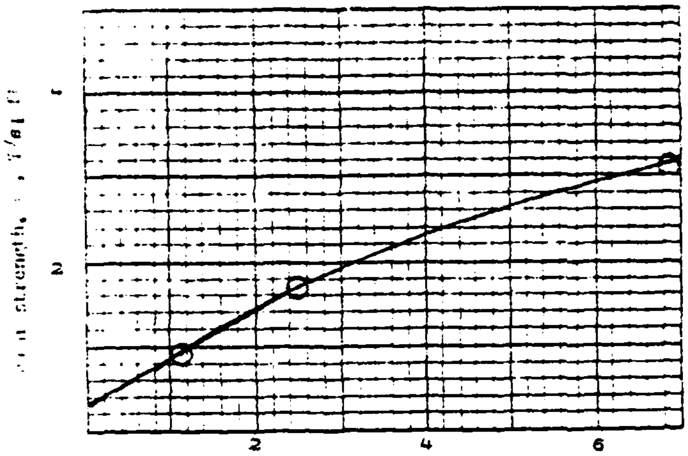
Shear speed .0554 in/hr No. D 197 Sample No. ST 6

28.0-30.0 ft Date

DIRECT SHEAR TEST REPORT

KANSAS CITY TESTING LABORATORY





Normal Stress, σ, T/sq ft

Test No.			1	2	3	
Initial	Water content	w_o	14.4%	14.2%	13.9%	%
	Void ratio	e_o	0.439	0.458	0.433	
	Saturation	S_o	88.6%	83.7%	86.7%	%
	Dry density lb/cu ft	γ_d	117.6	116.1	118.1	
Void ratio after consolidation		e_c	0.430	0.420	0.388	
Time for 50% consolidation, min		t_{50}	<0.5	<0.5	<1.0	
Final	Water content	w_f	16.5%	14.6%	15.1%	%
	Void ratio	e_f	0.450	0.423	0.376	
	Saturation	S_f	98.9%	93.1%	108.3%	%
Actual time to failure, min.		t_f	91	159	260	
Normal stress T/sq ft		σ	1.141	2.495	6.894	
Maximum shear strength, T/sq ft		τ	0.945	1.701	3.136	

Shear Values

tan

.3 TSF

Test Type: Check one

☐ Controlled stress ☒ Controlled strain

X 4.904 in. Square 1.0 in. Thickness

Tan mottled gray silty clay with sand

Thomas Hill 76-017-3-005

Burns and McDonnell

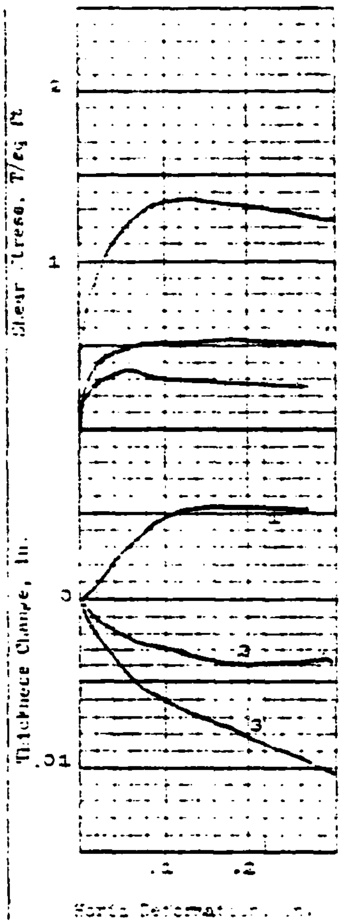
Q-test: consolidated 3 days, shear speed .0554 inches/hour

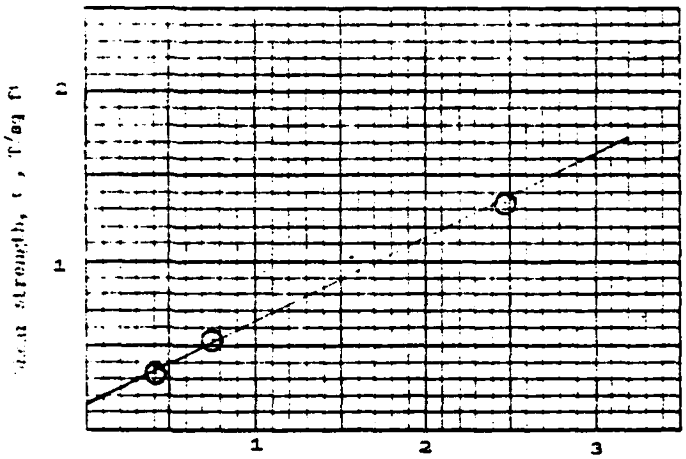
D 197 Sample No. ST 9

43.0-45.0 ft. Date

DIRECT SHEAR TEST REPORT

KANSAS CITY TESTING LABORATORY





Normal Stress, σ , T/sq ft

Test No.			1	2	3
Initial	Water content	w_o	17.9%	19.5%	18.7%
	Void ratio	e_o	0.572	0.597	0.575
	Saturation	S_o	86.3%	90.1%	89.7%
	Dry density lb/cu ft	γ_d	110.0	108.3	109.8
Void ratio after consolidation		e_c	0.560	0.572	0.525
Time for 50% consolidation, min		t_{50}	<0.5	<0.5	<0.5
Final	Water content	w_f	19.6%	19.7%	18.7%
	Void ratio	e_f	0.566	0.566	0.513
	Saturation	S_f	95.6%	96.1%	100.6%
Actual time to failure, min.		t_f	80	215	180
Normal stress T/sq ft		σ	0.408	0.774	2.495
Maximum shear strength, T/sq ft		τ	0.345	0.521	1.337

Shear Values

φ = ______

tan φ = ______

c = .2 TSF

Test Type: Shear Box ☐ Controlled stress [X] Controlled strain

Type of specimen: 4.904 in. Square 1.0 in. Thickness

Remarks:

Description: Olive mottled gray silty clay with trace of sand and gravel

Project: Thomas Hill 76-017-3-005

Burns and McDonnell

Area:

Boring No. D 199 Sample No. ST 3

Depth: 13.0-15.0 ft. Date

Type test: consolidated

3 days, shear speed .0354"/hr

DIRECT SHEAR TEST REPORT